US011082393B2

(12) **United States Patent**
Goel

(10) **Patent No.: US 11,082,393 B2**
(45) **Date of Patent: Aug. 3, 2021**

(54) **METHODS, SYSTEMS, AND COMPUTER READABLE MEDIA FOR ACTIVELY DISCOVERING AND TRACKING ADDRESSES ASSOCIATED WITH 5G AND NON-5G SERVICE ENDPOINTS**

(71) Applicant: **Oracle International Corporation**, Redwood Shores, CA (US)

(72) Inventor: **Yesh Goel**, Bangalore (IN)

(73) Assignee: **ORACLE INTERNATIONAL CORPORATION**, Redwood Shores, CA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **16/555,817**

(22) Filed: **Aug. 29, 2019**

(65) **Prior Publication Data**

US 2021/0067480 A1 Mar. 4, 2021

(51) **Int. Cl.**
G06F 15/16 (2006.01)
H04L 29/12 (2006.01)

(52) **U.S. Cl.**
CPC ***H04L 61/106*** (2013.01); ***H04L 61/10*** (2013.01); ***H04L 61/1511*** (2013.01); ***H04L 61/1541*** (2013.01)

(58) **Field of Classification Search**
CPC ... H04L 61/106; H04L 61/10; H04L 61/1511; H04L 61/1541
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

5,381,413 A 1/1995 Tobagi et al.
6,748,435 B1 6/2004 Wang et al.
(Continued)

FOREIGN PATENT DOCUMENTS

CN 105635345 B 2/2019
CN 109788078 A 5/2019
(Continued)

OTHER PUBLICATIONS

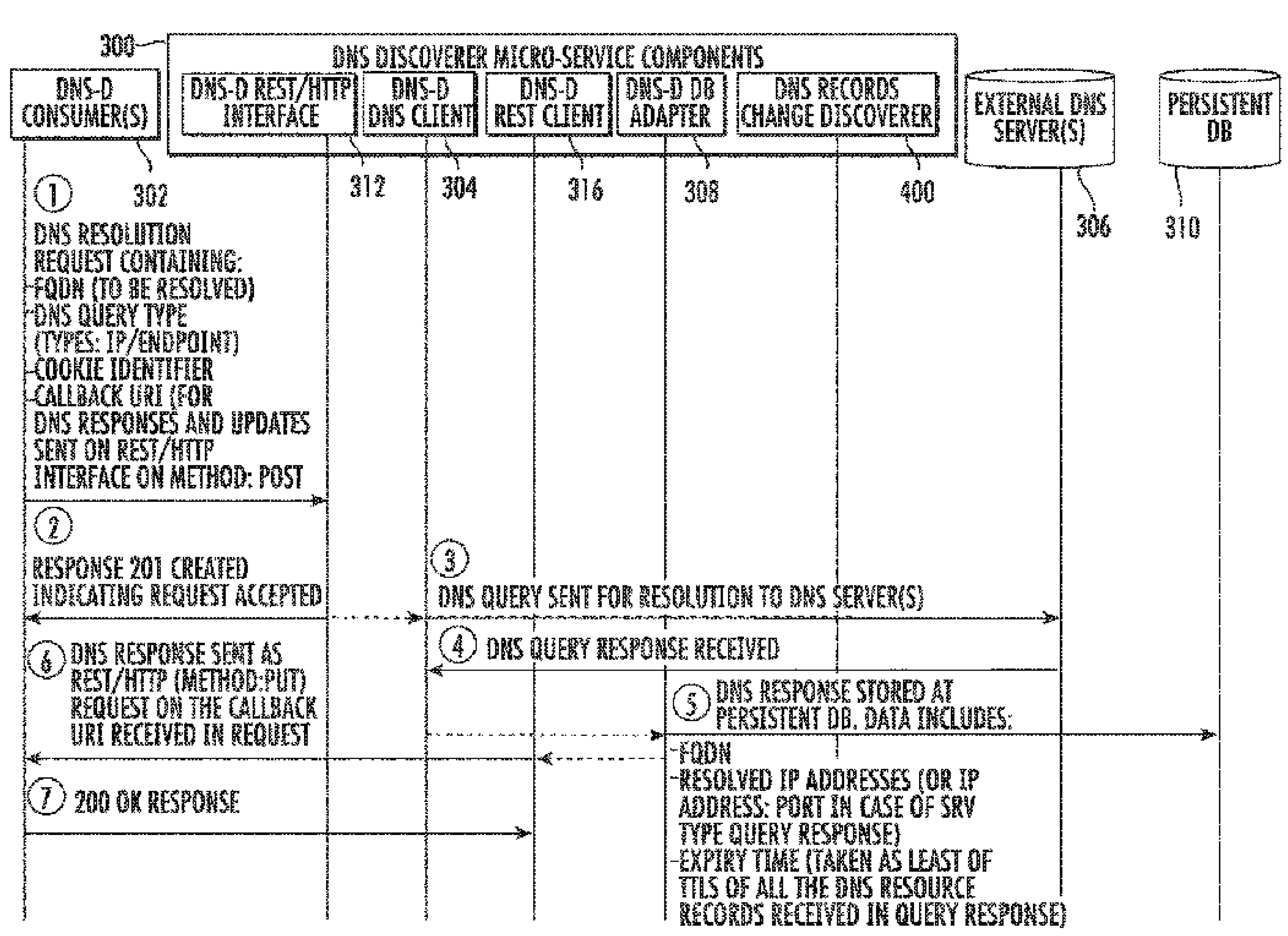
Notification of Transmittal of the International Search Report and the Written Opinion of the International Searching Authority, or the Declaration for International Application Serial No. PCT/US2019/053912 dated Dec. 18, 2019.
(Continued)

Primary Examiner — Cheikh T Ndiaye
(74) *Attorney, Agent, or Firm* — Jenkins, Wilson, Taylor & Hunt, P.A.

(57) **ABSTRACT**

A method for discovering and tracking addresses associated with producer network function (NF) service endpoints includes receiving a first domain name system (DNS) resolution request from a requesting node. The method further includes querying a DNS server using a fully qualified domain name (FQDN) extracted from the first DNS resolution request. The method further includes receiving a first response from the DNS server, the first response including an associated with a producer NF service endpoint associated with the FQDN and storing the address associated with the producer NF service endpoint in a database. The method further includes communicating the address associated with the producer NF service endpoint to the requesting node. The method further includes monitoring the FQDN for changes in address associated with the FQDN. The method further includes notifying the requesting node of the changes in address associated with the FQDN.

18 Claims, 8 Drawing Sheets



(56) **References Cited**

U.S. PATENT DOCUMENTS

7,782,776 B2	8/2010	Shankar et al.	
8,023,482 B2	9/2011	Gong et al.	
8,300,637 B1	10/2012	Bennett, III et al.	
8,645,565 B2	2/2014	Sparks et al.	
8,811,228 B2	8/2014	Lopez et al.	
8,879,431 B2	11/2014	Ridel et al.	
8,954,080 B2	2/2015	Janakiraman et al.	
9,246,762 B1	1/2016	Watkins	
9,667,590 B2	5/2017	Yan et al.	
10,097,504 B2	10/2018	Backholm	
10,285,155 B1	5/2019	Dodd-Noble et al.	
10,299,128 B1	5/2019	Suthar et al.	
10,361,843 B1	7/2019	Suthar et al.	
10,595,256 B1	3/2020	Marupaduga et al.	
10,609,154 B2	3/2020	Talebi Fard et al.	
10,609,530 B1 *	3/2020	Patil	H04W 24/04
10,616,934 B2	4/2020	Talebi Fard et al.	
10,652,098 B2	5/2020	Kim	
10,778,527 B2	9/2020	Assali et al.	
10,791,044 B1	9/2020	Krishan et al.	
10,819,636 B1	10/2020	Goel	
10,880,370 B2	12/2020	Seenappa et al.	
2003/0174649 A1	9/2003	Shankar et al.	
2003/0223414 A1	12/2003	Wong	
2004/0003069 A1	1/2004	Wong	
2004/0141473 A1	7/2004	Buot	
2004/0208183 A1	10/2004	Balachandran et al.	
2005/0193096 A1	9/2005	Yu et al.	
2006/0010224 A1	1/2006	Sekar et al.	
2007/0242738 A1	10/2007	Park et al.	
2009/0055835 A1	2/2009	Zhu	
2009/0141625 A1	6/2009	Ghai et al.	
2009/0222584 A1	9/2009	Josefsberg et al.	
2011/0078674 A1	3/2011	Ershov	
2011/0202604 A1	8/2011	Craig et al.	
2013/0029708 A1	1/2013	Fox et al.	
2013/0039176 A1	2/2013	Kanode et al.	
2013/0198269 A1	8/2013	Fleischman et al.	
2013/0272123 A1	10/2013	Lee et al.	
2014/0379901 A1	12/2014	Tseitlin et al.	
2015/0016266 A1	1/2015	Dumitrescu et al.	
2015/0071074 A1	3/2015	Zaidi et al.	
2015/0263987 A1	9/2015	Klein et al.	
2016/0142324 A1	5/2016	Vihtari et al.	
2016/0156513 A1	6/2016	Zhang et al.	
2016/0164788 A1	6/2016	Goel et al.	
2016/0234119 A1	8/2016	Zaidi et al.	
2016/0315743 A1	10/2016	Nagaraj et al.	
2016/0352588 A1	12/2016	Subbarayan et al.	
2017/0221015 A1	8/2017	June et al.	
2018/0039494 A1	2/2018	Lander et al.	
2018/0083882 A1	3/2018	Krishan et al.	
2018/0159780 A1	6/2018	Essigmann et al.	
2018/0183724 A1	6/2018	Callard et al.	
2018/0230556 A1 *	8/2018	Patterson	G06F 19/00
2018/0262625 A1	9/2018	McCarley et al.	
2018/0285794 A1	10/2018	Gray-Donald et al.	
2018/0324247 A1	11/2018	Hood et al.	
2018/0324646 A1	11/2018	Lee et al.	
2018/0343567 A1	11/2018	Ashrafi	
2019/0007366 A1	1/2019	Voegele et al.	
2019/0045351 A1	2/2019	Zee et al.	
2019/0075552 A1	3/2019	Yu et al.	
2019/0116486 A1	4/2019	Kim et al.	
2019/0116521 A1	4/2019	Qiao et al.	
2019/0140895 A1	5/2019	Ennis, Jr. et al.	
2019/0158364 A1	5/2019	Zhang et al.	
2019/0173740 A1	6/2019	Zhang et al.	
2019/0174561 A1	6/2019	Sivavakeesar	
2019/0182875 A1	6/2019	Talebi Fard et al.	
2019/0191348 A1	6/2019	Futaki et al.	
2019/0191467 A1	6/2019	Dao et al.	
2019/0222633 A1	7/2019	Howes et al.	
2019/0223093 A1	7/2019	Watfa et al.	
2019/0230556 A1	7/2019	Lee	
2019/0261244 A1	8/2019	Jung et al.	
2019/0268270 A1	8/2019	Fattah	
2019/0306251 A1 *	10/2019	Talebi Fard	H04L 67/12
2019/0306907 A1	10/2019	Andreoli-Fang et al.	
2019/0313236 A1	10/2019	Lee et al.	
2019/0313437 A1	10/2019	Jung et al.	
2019/0313469 A1	10/2019	Karampatsis et al.	
2019/0335002 A1	10/2019	Bogineni et al.	
2019/0335534 A1	10/2019	Atarius et al.	
2019/0342229 A1	11/2019	Khinvasara et al.	
2019/0342921 A1	11/2019	Loehr et al.	
2019/0349901 A1	11/2019	Basu Mallick et al.	
2019/0357092 A1	11/2019	Jung et al.	
2019/0380031 A1	12/2019	Suthar et al.	
2019/0394284 A1	12/2019	Baghel et al.	
2019/0394624 A1	12/2019	Karampatsis et al.	
2019/0394833 A1	12/2019	Talebi Fard et al.	
2020/0007632 A1 *	1/2020	Landais	H04L 67/16
2020/0008069 A1	1/2020	Zhu et al.	
2020/0028920 A1 *	1/2020	Livanos	H04W 48/16
2020/0045753 A1	2/2020	Dao et al.	
2020/0045767 A1	2/2020	Velev et al.	
2020/0053670 A1	2/2020	Jung et al.	
2020/0053724 A1	2/2020	MolavianJazi et al.	
2020/0053828 A1	2/2020	Bharatia et al.	
2020/0059420 A1	2/2020	Abraham	
2020/0059856 A1	2/2020	Cui et al.	
2020/0084663 A1	3/2020	Park et al.	
2020/0092423 A1	3/2020	Qiao et al.	
2020/0092424 A1	3/2020	Qiao et al.	
2020/0127916 A1	4/2020	Krishan	
2020/0136911 A1	4/2020	Assali et al.	
2020/0177629 A1	6/2020	Hooda et al.	
2020/0313996 A1	10/2020	Krishan et al.	

FOREIGN PATENT DOCUMENTS

EP	2 575 303 A1	4/2013		
WO	WO 2017/143915 A1	8/2017		
WO	WO 2018/174021 A1	9/2018		
WO	WO 2018/174516 A1	9/2018		
WO	WO 2019/034609 A1	2/2019		
WO	WO 2019/062596 A1	4/2019		
WO	WO 2019/076273 A1	4/2019		
WO	WO-2019144321 A1 *	8/2019	H04L 61/1511	
WO	WO 2019/220172 A1	11/2019		
WO	WO 2020/091934 A1	5/2020		
WO	WO 2020/263486 A1	12/2020		

OTHER PUBLICATIONS

Commonly-assigned, co-pending U.S. Appl. No. 16/697,021 for "Methods, Systems, and Computer Readable Media for Diameter-Peer-Wide Egress Rate Limiting at Diameter Relay Agent (DRA)," (Unpublished, filed Nov. 27, 2019).

"3rd Generation Partnership Project; Technical Specification Group Services and System Aspects; Architecture enhancements to facilitate communications with packet data networks and applications (Release 16)," 3GPP TS 23.682, V16.4.0, pp. 1-30 (Sep. 2019).

"Diameter and Diameter Applications," Alcatel-Lucent, http://infodoc.alcatel-lucent.com/html/0_add-h-f/93-0098-HTML/7750_SR_OS_Triple_Play_Guide/GX-PolicyMgmt.html, pp. 1-40 (Aug. 22, 2019).

"3rd Generation Partnership Project; Technical Specification Group Radio Access Network; NG-RAN; NG Application Protocol (NGAP) (Release 15)," 3GPP TS 38.413, V15.4.0, pp. 1-328 (Jul. 2019).

Commonly-assigned, co-pending U.S. Appl. No. 16/453,955 for "Methods, Systems, and Computer Readable Media for Producer Network Function (NF) Service Instance Wide Egress Rate Limiting at Service Communication Proxy (SCP)," (Unpublished, filed Jun. 26, 2019).

"3rd Generation Partnership Project; Technical Specification Group Core Network and Terminals; 5G System; Network Function Repository Services; Stage 3 (Release 16)," 3GPP TS 29.510, V16.0.0, pp. 1-135 (Jun. 2019).

"3rd Generation Partnership Project; Technical Specification Group Core Network and Terminals; 5G System; Restoration Procedures (Release 16)," 3GPP TS 23.527, V16.0.0, pp. 1-19 (Jun. 2019).

(56) **References Cited**

OTHER PUBLICATIONS

"3rd Generation Partnership Project; Technical Specification Group Core Network and Terminals; Numbering, addressing and identification (Release 15)," 3GPP TS 23.003, V15.7.0, pp. 1-131 (Jun. 2019).
"Class of Service Feature Guide (Routers and EX9200 Switches)," Junos® OS, Juniper Networks, pp. 1-1530 (Apr. 10, 2019).
"3rd Generation Partnership Project; Technical Specification Group Services and System Aspects; System Architecture and 5G; Stage 2 (Release 16)," 3GPP TS 23.501, V16.0.0, pp. 1-318 (Mar. 2019).
Commonly-assigned, co-pending U.S. Appl. No. 16/369,691 for "Methods, System and Computer Readable Media for Handling Multiple Versions of Same Service Provided by Producer Network Functions (NFs)," (Unpublished, filed Mar. 29, 2019).
Penttinen, "5G Explained: Security and Deployment of Advanced Mobile Communications," Chapter 6, Section 6.3.8 NRF, 2 pages (Feb. 2019).
"Oracle Communications Diameter Signaling Router," Release Notice, Release 8.3, E93179 Revision 02, Oracle, pp. 1-98 (Dec. 2018).
"3rd Generation Partnership Project; Technical Specification Group Network and Terminals; 5G Systems; Network Function Repository Services; Stage 3 (Release 15)," 3GPP TS 29.510, V15.2.0, pp. 1-113 (Dec. 2018).
"3rd Generation Partnership Project; Technical Specification Group Network and Terminals; 5G Systems; Principles and Guidelines for Services Definition; Stage 3 (Release 15)," 3GPP TS 29.501, V15.2.0, pp. 1-66 (Dec. 2018).
"3rd Generation Partnership Project; Technical Specification Group Services and System Aspects; Study on Enhancements to the Service-Based Architecture (Release 16)," 3GPP TR 23.742, V16.0.0, pp. 1-131 (Dec. 2018).
"Addressing 5G Network Function Requirements," Intel® FPGAs and Intel PAC 5G QoS and IPSec Benchmarking, White Paper, pp. 1-8 (Oct. 2018).
"CPS vDRA Configuration Guide," Release 18.3.0 (Restricted Release)(1), Cisco, pp. 1-130 (Sep. 14, 2018).
"How To Do Rate Limiting of Diameter Messages Using NetScaler," Citrix Systems Inc., pp. 1-3 (Sep. 4, 2018).
"5G; 5G System; Technical Realization of Service Based Architecture; Stage 3 (3GPP TS 29.500 version 15.0.0 Release 15)," ETSI TS 129 500, V15.0.0, pp. 1-29 (Jul. 2018).
"3rd Generation Partnership Project; Technical Specification Group Services and System Aspects; Study on Enhancements to the Service-Based Architecture (Release 16)," 3GPP TR 23.742, V0.3.0, pp. 1-64 (Jul. 2018).
"3rd Generation Partnership Project; Technical Specification Group Services and System Aspects; Study on Enhancements to the Service-Based Architecture (Release 16)," 3GPP TR 23.742, V0.2.0, pp. 1-39 (Jun. 2018).
"5G; Procedures for the 5G System (3GPP TS 23.502 version 15.2.0 Release 15)," ETSI TS 123 502 V15.2.0, pp. 1-46 (Jun. 2018).
"Cisco Ultra 5G Packet Core Solution," Cisco, White paper, https://www.cisco.com/c/dam/en/us/products/collateral/routers/network-convergence-system-500-series-routers/white-paper-c11-740360.pdf, pp. 1-11 (2018).
Scholl et al., "An API First Approach to Microservices Development," Oracle, https://blogs.oracle.com/developers/an-api-first-approach-to-microservices-development, pp. 1-12 (Nov. 8, 2017).
Brown et al., "Service-Based Architecture for 5G Core Networks," Huawei, Heavu Reading, https://www.3g5g.co/uk/5G/5Gtech_6004_2017_11_Service-Based-Architecture-for-5G-Core-Networks_HR_Huawei.pdf, pp. 1-12 (Nov. 2017).
"3rd Generation Partnership Project; Technical Specification Group Services and System Aspects; System Architecture for the 5G System; Stage 2 (Release 15)," 3GPP TS 23.501, V1.5.0, pp. 1-170 (Nov. 2017).
"Pseudo-CR on Service Discovery and Registration using NRF service," Ericsson, 3GPP TSG CT4 Meeting #79, 3GPP TR 29.891—v0.3.0, pp. 1-4 (Aug. 21-25, 2017).
Carlton et al., "HTTP and DNS in a 5G World," https://www.computerworld.com/article/3204594/http-and-dns-in-a-5g-world.html, pp. 1-5 (Jun. 30, 2017).
Benacer et al., "A High-Speed Traffic Manager Architecture for Flow-Based Networking," pp. 1-4 (2017).
"Dynamically Reconfigurable Optical-Wireless Backhaul/Fronthaul with Cognitive Control Plane for Small Cells and Cloud-RANs; D3.1 Analysis of state of the art on scalable control plane design and techniques for user mobility awareness. Definition of 5G-XHaul control plane requirements," European Commission, 5G-XHaul, pp. 1-107 (Jun. 31, 2016).
"Multi-Layer Security Protection for Signaling Networks," Oracle Communications, Oracle white paper, pp. 1-9 (Jan. 2016).
Kantola et al., "Policy-based communications for 5G mobile with customer edge switching," Security and Communication Networks, vol. 9, pp. 3070-3082 (2016).
Preston-Werner, "Semantic Versioning 2.0.0", Oracle, pp. 1-5 (Jun. 2013).
Fajardo et al., "Diameter Nased Protocol," Internet Engineering Task Force (IETF) Request for Comments: 6733, pp. 1-152 (Oct. 2012).
Gulbrandsen et al, "A DNS RR for specifying the location of services (DNS SRV)," RFC 2782, pp. 1-12 (Feb. 2000).
Non-Final Office Action for U.S. Appl. No. 16/176,920 dated Mar. 6, 2020.
Commonly-assignesd, co-pending U.S. Appl. No. 16/176, 920 for "Methods, Systems, and Computer Readable Media for Providing a Service Proxy Function in a Telecommunications Network Core Using a Service-Based Architecture," (Unpublished, filed Oct. 31, 2018).
Applicant-Initiated Interview Summary for U.S. Appl. No. 16/176,920 dated Apr. 1, 2020.
Final Office Action for U.S. Appl. No. 16/356,446 dated Sep. 8, 2020.
Notice of Allowance and Fee(s) Due and Examiner-Initiated Interview Summary for U.S. Appl. No. 16/453,955 dated Aug. 26, 2020.
Notification of the Transmittal of the International Search Report and the Written Opinion of the International Searching Authority, or the Declaration for International Application No. PCT/US2020/034723 dated Aug. 17, 2020.
Notification of Transmittal of the International Search Report and the Written Opinion of the International Searching Authority, or the Declaration for International Application Serial No. PCT/US2020/035004 dated Jul. 7, 2020.
Notice of Allowance and Fee(s) Due for U.S. Appl. No. 16/369,691 dated May 12, 2020.
Non-Final Office Action for U.S. Appl. No. 16/356,446 dated May 11, 2020.
Notice of Allowance and Fee(s) Due for U.S. Appl. No. 16/176,920 dated Apr. 16, 2020.
"3rd Generation Partnership Project; Technical Specification Group Core Network and Terminals; 5G Systems; Network Function Repository Services; Stage 3 (Release 16)," 3GPP TS 29.510 V.16.1.1, pp. 1-150 (Oct. 2019).
"3rd Generation Partnership Project; Technical Specification Group Core Network and Terminals; 5G System; Technical Realization of Service Based Architecture; Stage 3 (Release 16)," 3GPP TS 29.500 V16.1.0, pp. 1-43 (Sep. 2019).
"3rd Generation Partnership Project; Technical Specification Group Service and System Aspects; System Architecture for the 5G System (5GS); Stage 2 (Release 16)," 3GPP TS 23.501 V16.2.0, pp. 1-391 (Sep. 2019).
Cheshire et al., "Apple's DNS Long-Lived Queries protocol," Network Working Group, Apple, Inc., pp. 1-26 (Aug. 22, 2019).
Fielding et al. "Hypertext Transfer Protocol (HTTP/1.1): Semantics and Content", Internet Engineering Taskforce (IETF) Request for Comments: 7231, IEFT RFC 7231, pp. 1-102 (Jun. 2014).
Abley et al., "A Mechanism for Remote-Triggered DNS Cache Flushes (DNS FLUSH)," Network Working Group, Google, pp. 1-12 (Jun. 24, 2013).
Nichols et al., "Definition of the Differentiated Services Field (DS Field) in the IPv4 and IPv6 Headers," Internet Engineering Task

(56) **References Cited**

OTHER PUBLICATIONS

Force (IEFT) Network Working Group Request for Comments (RFC) 2474, The Internet Society, pp. 1-20 (Dec. 1998).
Commonly-assigned, co-pending U.S. Appl. No. 17/074,553 for "Methods, Systems, and Computer Readable Media for Actively Discovering and Tracking Addresses Associated with 4G Service Endpoints," (Unpublished, filed Oct. 19, 2020).
Non-Final Office Action for U.S. Appl. No. 16/697,021 dated Sep. 29, 2020.
Li et al., "Mobile Edge Computing Platform Deployment in 4G LTE Networks: A Middlebox Approach," https://www.usenix.org/system/files/conference/hotedge18/hotedge18-papers-li.pdf, 6 pages (2018).
"3rd Generation Partnership Project; Technical Specification Group Core Network and Terminals; Domain Name System Procedures; Stage 3 (Release 13)," 3GPP TS 29.303 V13.4.0, pp. 1-69 (Jun. 2016).
"LTE and Beyond," https://ytd2525.wordpress.com/2013/03/06/lte-and-beyond/, 3 pages (2013).
Commonly-assigned, co-pending U.S. Appl. No. 17/082,871 for "Methods, Systems, and Computer Readable Media for Rank Processing for Network Function Selection," (Unpublished, filed Oct. 28, 2020).
Commonly-assigned, co-pending U.S. Appl. No. 16/945,794 for "Methods, Systems, And Computer Readable Media For Preferred Network Function (NF) Location Routing Using Service Communications Proxy (SCP)," (Unpublished, filed Jul. 31, 2020).
"3rd Generation Partnership Project; Technical Specification Group Core Network and Terminals; 5G System; Network Function Repository Services; Stage 3 (Release 16)," 3GPP TS 29.510 V16.4.0, pp. 1-206 (Jul. 2020).
"3rd Generation Partnership Project; Technical Specification Group Services and System Aspects; Procedures for the 5G System (5GS); Stage 2 (Release 16)," 3GPP TS 23.502 V16.4.0, pp. 1-582 (Mar. 2020).
"3rd Generation Partnership Project; Technical Specification Group Services and System Aspects; System architecture for the 5G System (5GS); Stage 2 (Release 16)," 3GPP TS 23.501 V16.4.0, pp. 1-430 (Mar. 2020).
Applicant-Initiated Interview Summary for U.S. Appl. No. 16/697,021 (dated Jan. 26, 2021).
International Search Report and Written Opinion for Patent Cooperation Treaty Application Serial No. PCT/US2020/061885 (dated Feb. 4, 2021).
International Search Report and Written Opinion for Patent Cooperation Treaty Application Serial No. PCT/US2020/057712 (dated Feb. 2, 2021).
Cheshire, S. et al., "Apple's DNS Long-Lived Queries protocol draft-sekar-dns-llq-06," Internet Engineering Task Force (IETF), pp. 1-26 (Aug. 23, 2019).
Final Office Action for U.S. Appl. No. 16/697,021 (dated Feb. 2, 2021).

* cited by examiner

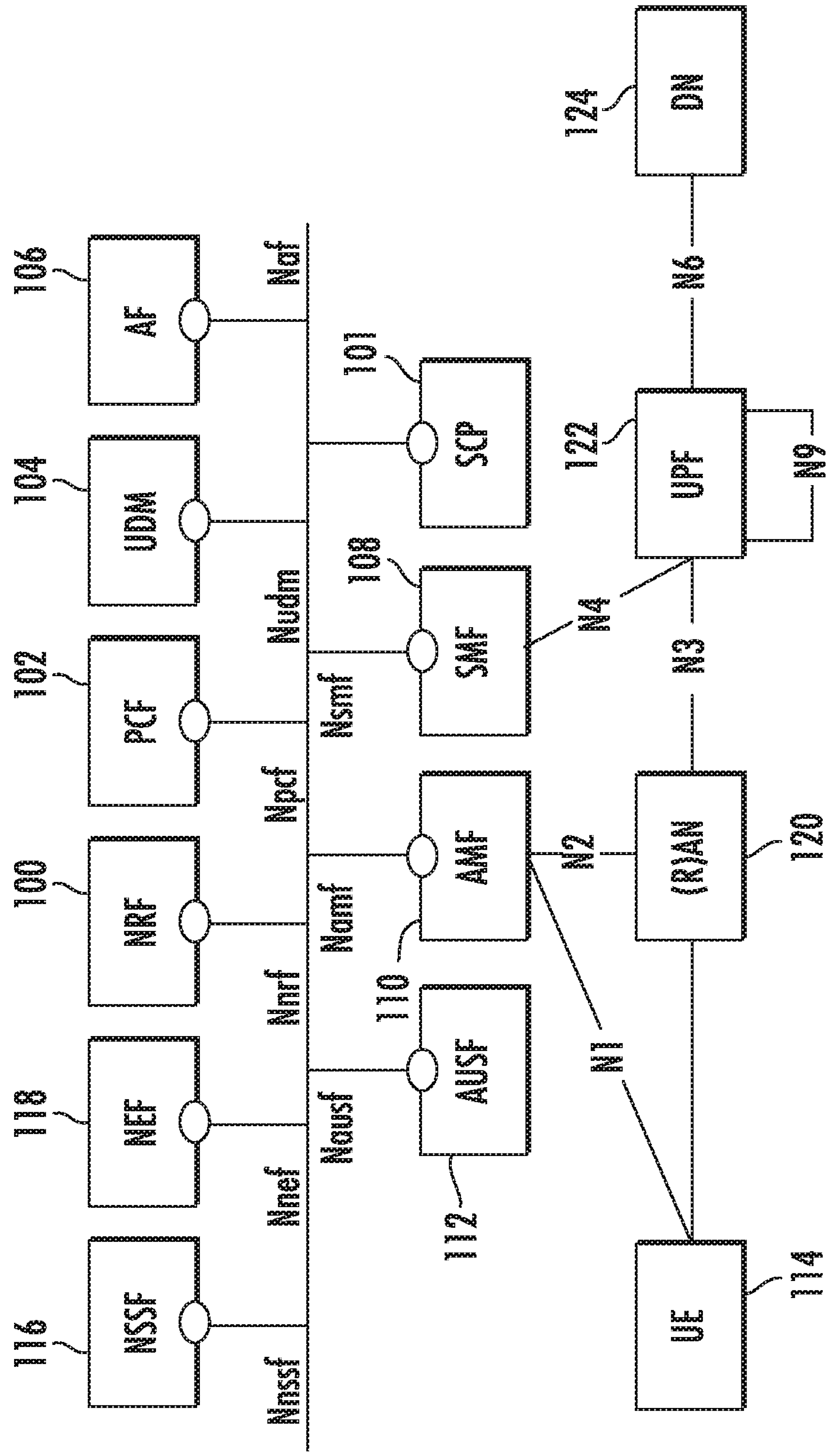

AF
106
UDM
104
PCF
102
NRF
100
NEF
118
NSSF
116
Naf
Nudm
Npcf
Nnrf
Nnef
Nnssf
SCP
101
SMF
108
Nsmf
AMF
110
Namf
AUSF
112
Nausf
DN
124
N6
UPF
122
N9
N4
N3
N2
(R)AN
120
N1
UE
114

FIG. 1

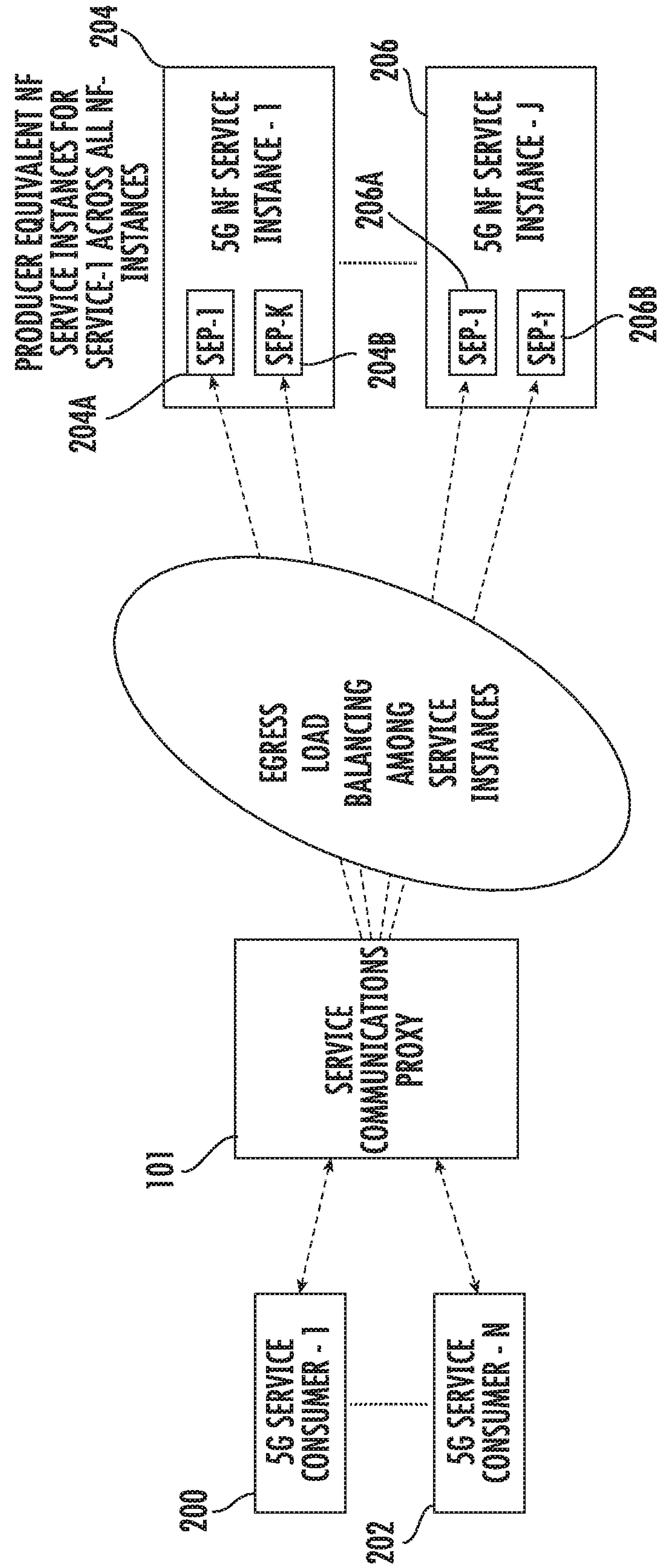

PRODUCER EQUIVALENT NF SERVICE INSTANCES FOR SERVICE-1 ACROSS ALL NF-INSTANCES
204
5G NF SERVICE INSTANCE - 1
SEP-1
SEP-K
204A
204B
206
5G NF SERVICE INSTANCE - J
206A
SEP-1
SEP-t
206B
EGRESS LOAD BALANCING AMONG SERVICE INSTANCES
101
SERVICE COMMUNICATIONS PROXY
200
5G SERVICE CONSUMER - 1
202
5G SERVICE CONSUMER - N

FIG. 2

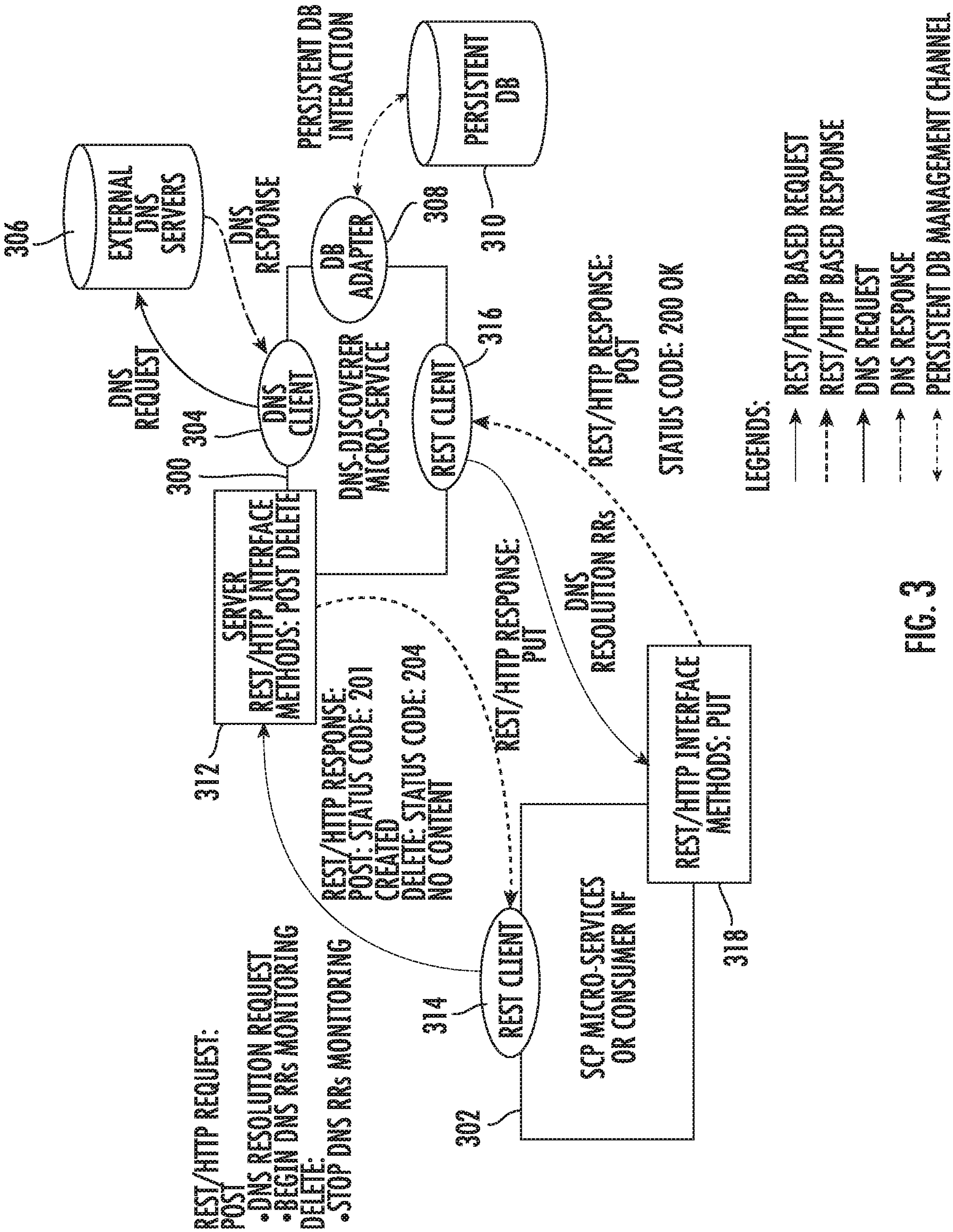

306
EXTERNAL DNS SERVERS
DNS REQUEST
DNS RESPONSE
PERSISTENT DB INTERACTION
PERSISTENT DB
310
308
DB ADAPTER
304
DNS CLIENT
300
DNS-DISCOVERER MICRO-SERVICE
REST CLIENT
316
REST/HTTP RESPONSE: POST
STATUS CODE: 200 OK
SERVER
REST/HTTP INTERFACE
METHODS: POST DELETE
312
REST/HTTP RESPONSE: PUT
DNS RESOLUTION RRs
REST/HTTP RESPONSE:
POST: STATUS CODE: 201 CREATED
DELETE: STATUS CODE: 204 NO CONTENT
REST/HTTP INTERFACE
METHODS: PUT
318
REST CLIENT
314
SCP MICRO-SERVICES OR CONSUMER NF
302
REST/HTTP REQUEST:
POST
•DNS RESOLUTION REQUEST
•BEGIN DNS RRs MONITORING
DELETE:
•STOP DNS RRs MONITORING
LEGENDS:
REST/HTTP BASED REQUEST
REST/HTTP BASED RESPONSE
DNS REQUEST
DNS RESPONSE
PERSISTENT DB MANAGEMENT CHANNEL

FIG. 3

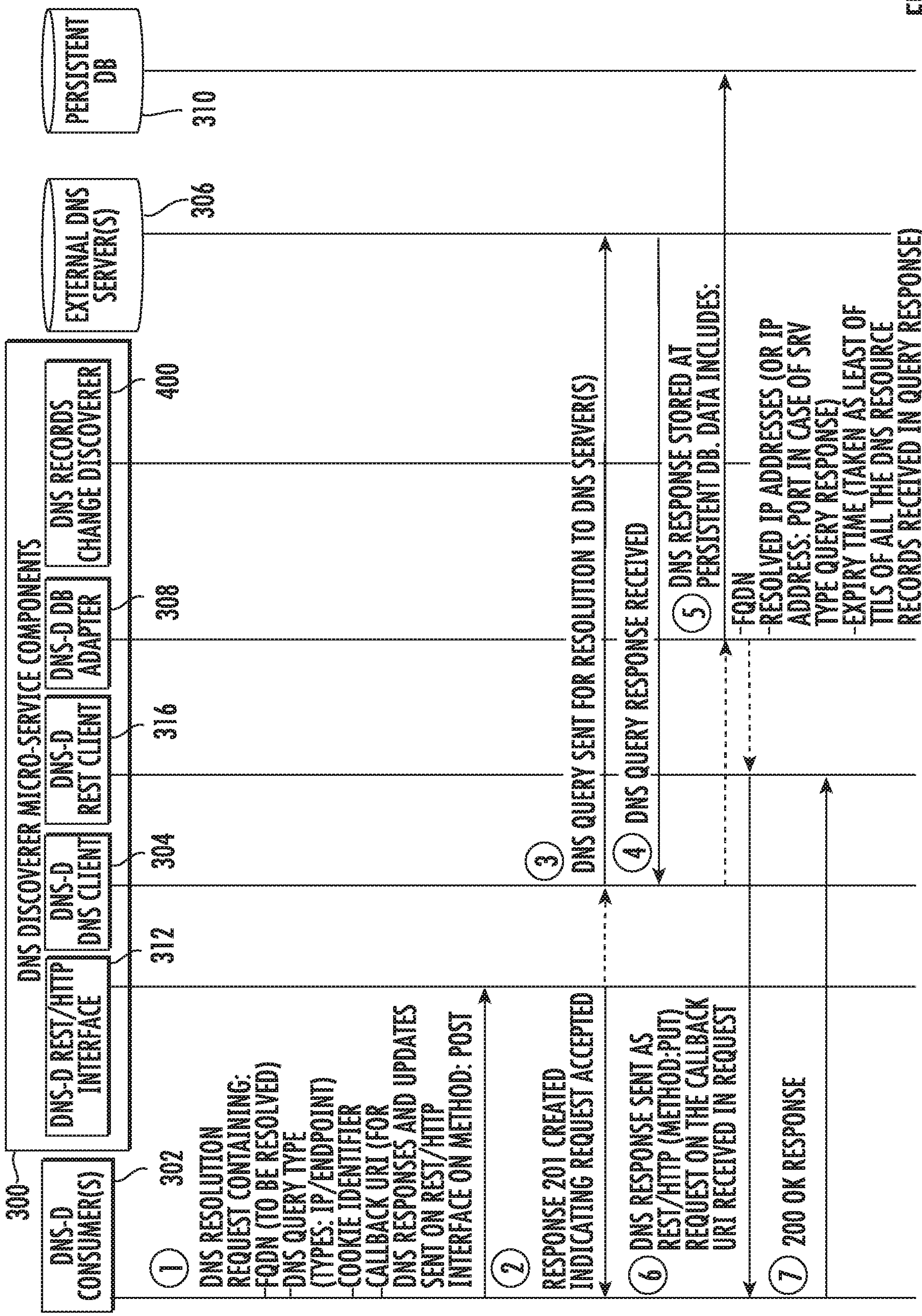

300
DNS-D CONSUMER(S)
302
DNS DISCOVERER MICRO-SERVICE COMPONENTS
DNS-D REST/HTTP INTERFACE
312
DNS-D DNS CLIENT
304
DNS-D REST CLIENT
316
DNS-D DB ADAPTER
308
DNS RECORDS CHANGE DISCOVERER
400
EXTERNAL DNS SERVER(S)
306
PERSISTENT DB
310
1
DNS RESOLUTION REQUEST CONTAINING:
-FQDN (TO BE RESOLVED)
-DNS QUERY TYPE (TYPES: IP/ENDPOINT)
-COOKIE IDENTIFIER
-CALLBACK URI (FOR DNS RESPONSES AND UPDATES SENT ON REST/HTTP INTERFACE ON METHOD: POST
2
RESPONSE 201 CREATED INDICATING REQUEST ACCEPTED
3
DNS QUERY SENT FOR RESOLUTION TO DNS SERVER(S)
4
DNS QUERY RESPONSE RECEIVED
5
DNS RESPONSE STORED AT PERSISTENT DB. DATA INCLUDES:
-FQDN
-RESOLVED IP ADDRESSES (OR IP ADDRESS: PORT IN CASE OF SRV TYPE QUERY RESPONSE)
-EXPIRY TIME (TAKEN AS LEAST OF TTLS OF ALL THE DNS RESOURCE RECORDS RECEIVED IN QUERY RESPONSE)
6
DNS RESPONSE SENT AS REST/HTTP (METHOD:PUT) REQUEST ON THE CALLBACK URI RECEIVED IN REQUEST
7
200 OK RESPONSE

FIG. 4

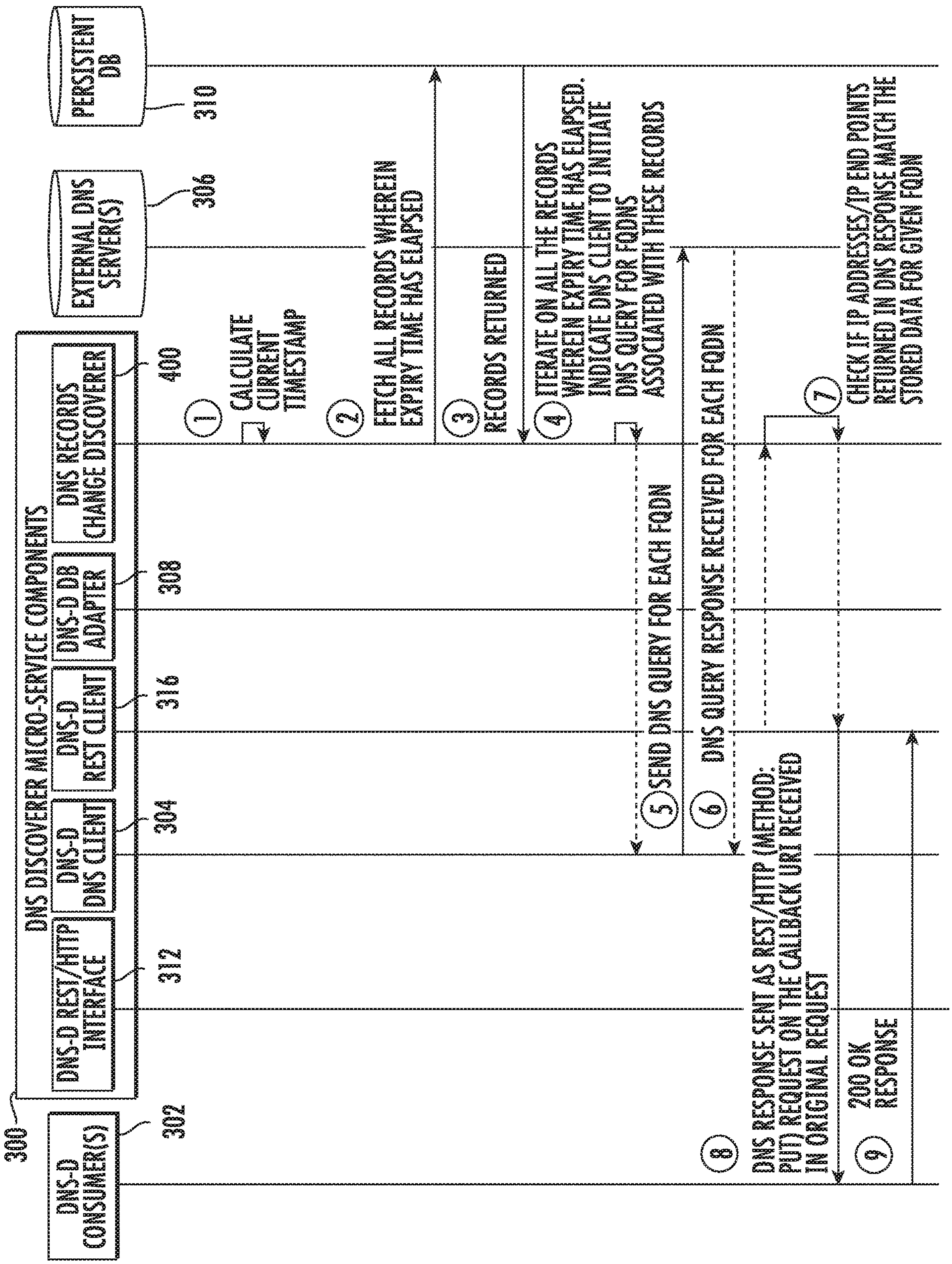

300
DNS DISCOVERER MICRO-SERVICE COMPONENTS
DNS-D CONSUMER(S)
302
DNS-D REST/HTTP INTERFACE
312
DNS-D DNS CLIENT
304
DNS-D REST CLIENT
316
DNS-D DB ADAPTER
308
DNS RECORDS CHANGE DISCOVERER
400
EXTERNAL DNS SERVER(S)
306
PERSISTENT DB
310
1 CALCULATE CURRENT TIMESTAMP
2 FETCH ALL RECORDS WHEREIN EXPIRY TIME HAS ELAPSED
3 RECORDS RETURNED
4 ITERATE ON ALL THE RECORDS WHEREIN EXPIRY TIME HAS ELAPSED. INDICATE DNS CLIENT TO INITIATE DNS QUERY FOR FQDNS ASSOCIATED WITH THESE RECORDS
5 SEND DNS QUERY FOR EACH FQDN
6 DNS QUERY RESPONSE RECEIVED FOR EACH FQDN
7 CHECK IF IP ADDRESSES/IP END POINTS RETURNED IN DNS RESPONSE MATCH THE STORED DATA FOR GIVEN FQDN
8 DNS RESPONSE SENT AS REST/HTTP (METHOD: PUT) REQUEST ON THE CALLBACK URI RECEIVED IN ORIGINAL REQUEST
9 200 OK RESPONSE

FIG. 5

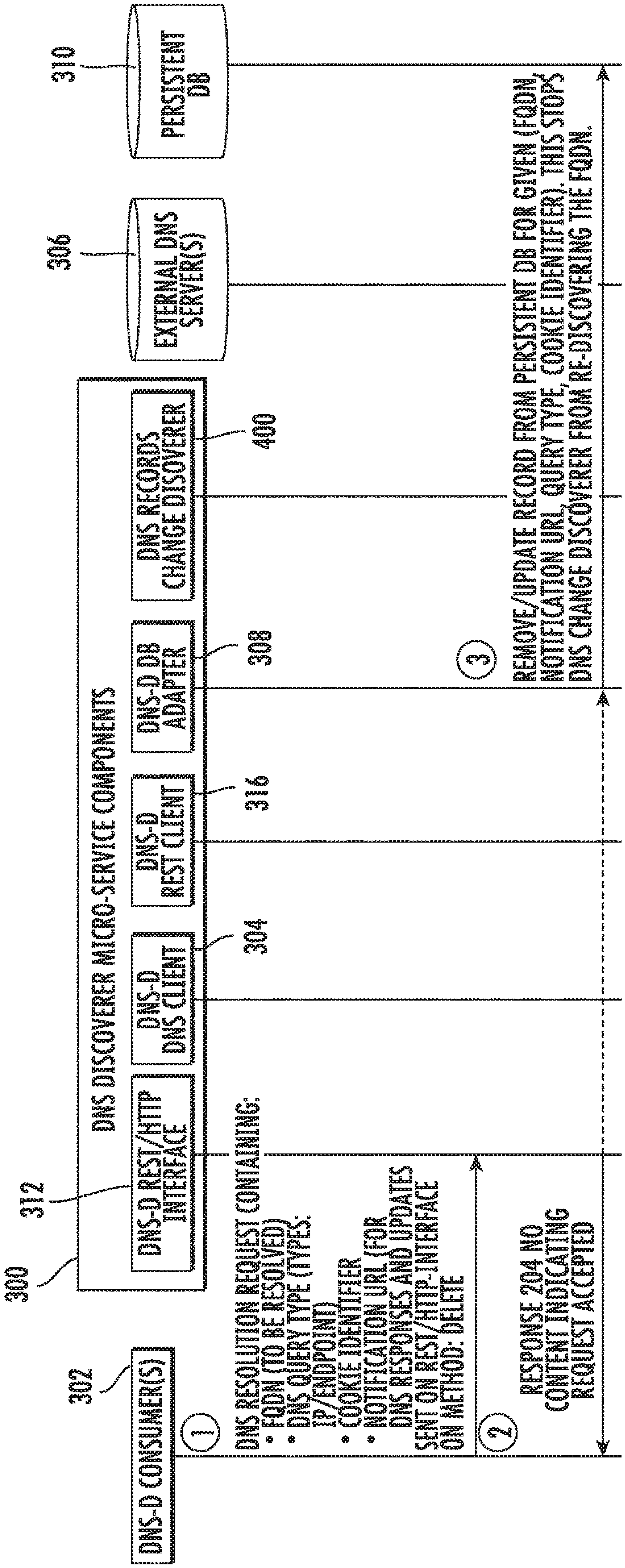

310
PERSISTENT DB
306
EXTERNAL DNS SERVER(S)
300
DNS DISCOVERER MICRO-SERVICE COMPONENTS
312
DNS-D REST/HTTP INTERFACE
DNS-D DNS CLIENT
304
DNS-D REST CLIENT
316
DNS-D DB ADAPTER
308
DNS RECORDS CHANGE DISCOVERER
400
302
DNS-D CONSUMER(S)
1
DNS RESOLUTION REQUEST CONTAINING:
• FQDN (TO BE RESOLVED)
• DNS QUERY TYPE (TYPES: IP/ENDPOINT)
• COOKIE IDENTIFIER
• NOTIFICATION URL (FOR DNS RESPONSES AND UPDATES SENT ON REST/HTTP-INTERFACE
ON METHOD: DELETE
2
RESPONSE 204 NO CONTENT INDICATING REQUEST ACCEPTED
3
REMOVE/UPDATE RECORD FROM PERSISTENT DB FOR GIVEN (FQDN, NOTIFICATION URL, QUERY TYPE, COOKIE IDENTIFIER). THIS STOPS DNS CHANGE DISCOVERER FROM RE-DISCOVERING THE FQDN.

FIG. 6

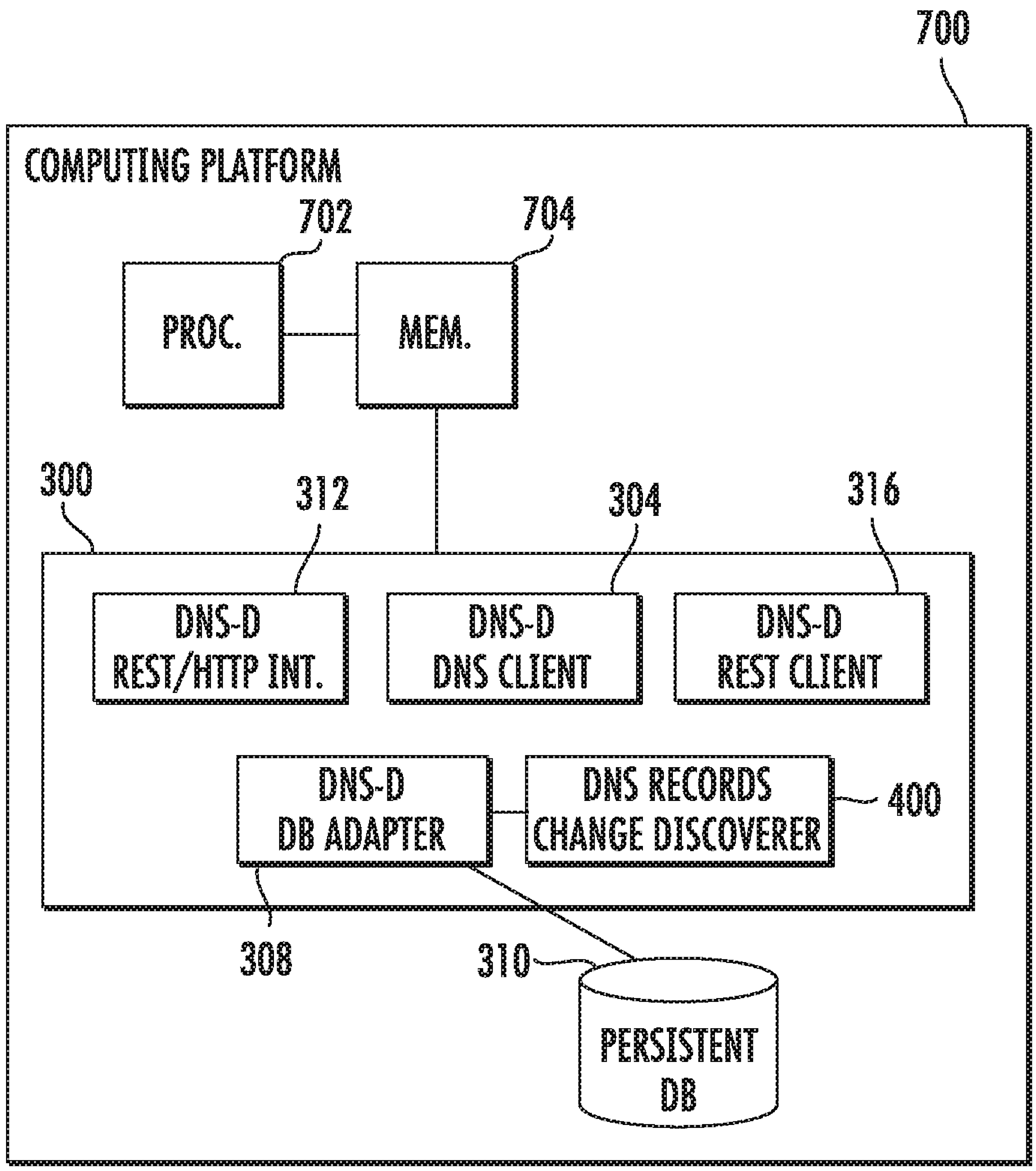

700
COMPUTING PLATFORM
702
704
PROC.
MEM.
300
312
304
316
DNS-D
REST/HTTP INT.
DNS-D
DNS CLIENT
DNS-D
REST CLIENT
DNS-D
DB ADAPTER
DNS RECORDS
CHANGE DISCOVERER
400
308
310
PERSISTENT
DB

FIG. 7

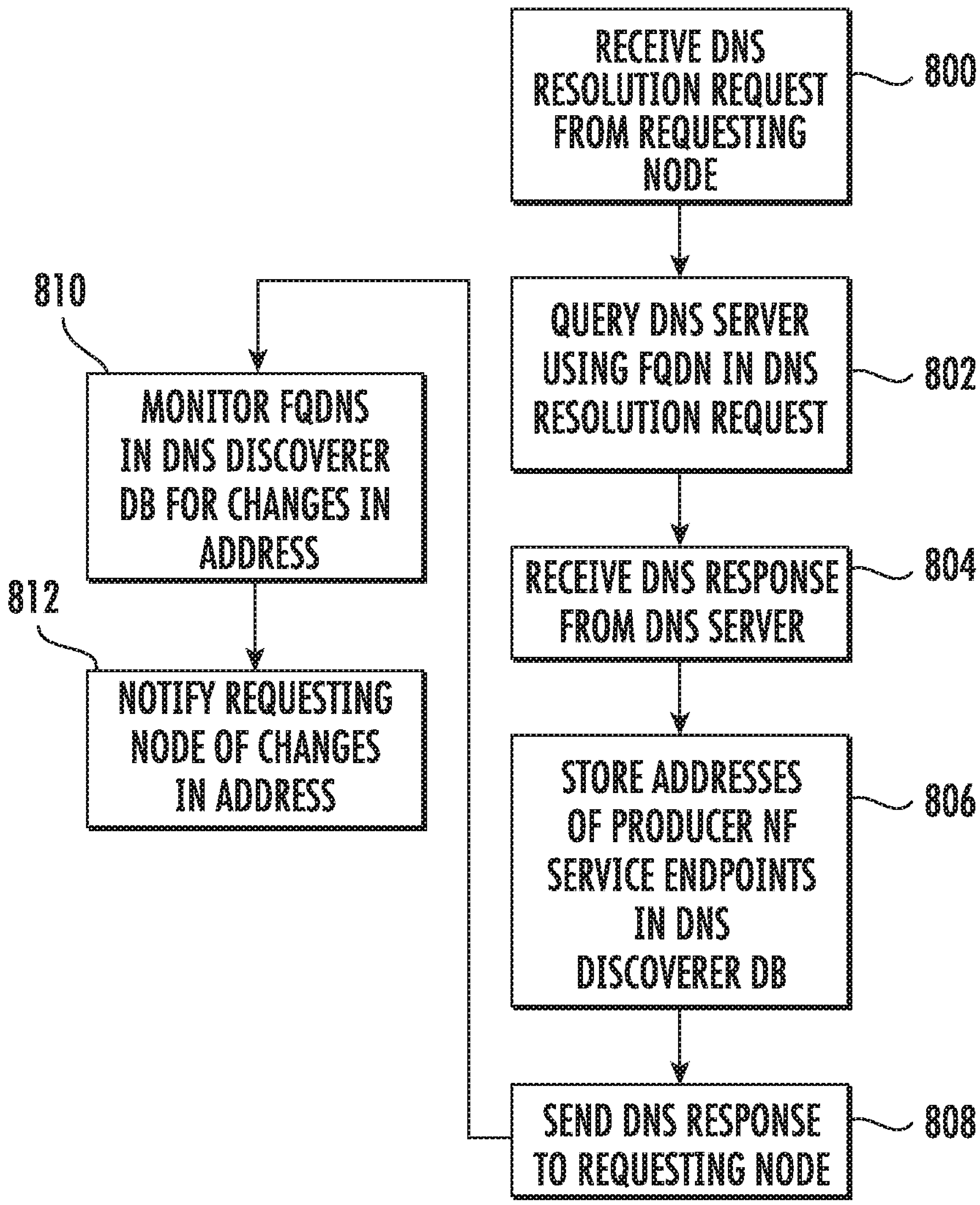

RECEIVE DNS RESOLUTION REQUEST FROM REQUESTING NODE
800
QUERY DNS SERVER USING FQDN IN DNS RESOLUTION REQUEST
802
RECEIVE DNS RESPONSE FROM DNS SERVER
804
STORE ADDRESSES OF PRODUCER NF SERVICE ENDPOINTS IN DNS DISCOVERER DB
806
SEND DNS RESPONSE TO REQUESTING NODE
808
810
MONITOR FQDNS IN DNS DISCOVERER DB FOR CHANGES IN ADDRESS
812
NOTIFY REQUESTING NODE OF CHANGES IN ADDRESS

FIG. 8

METHODS, SYSTEMS, AND COMPUTER READABLE MEDIA FOR ACTIVELY DISCOVERING AND TRACKING ADDRESSES ASSOCIATED WITH 5G AND NON-5G SERVICE ENDPOINTS

TECHNICAL FIELD

The subject matter described herein relates to discovering address information associated with service endpoints in a telecommunications network. More particularly, the subject matter described herein relates to methods, systems, and computer readable media for actively discovering and tracking addresses associated with 5G and non-5G service endpoints.

BACKGROUND

In telecommunications networks, a service endpoint is an address on a network node that uniquely identifies an entity that provides service to service consumers. The service endpoint can include an Internet protocol (IP) address or a combination of IP address and transport layer port number, which is also referred to as an IP endpoint.

In 5G telecommunications networks, the network node that provides service is referred to as a producer network function (NF). A network node that consumes services is referred to as a consumer NF. A network function can be both a producer NF and a consumer NF depending on whether it is consuming or providing service.

A given producer NF may have many service endpoints. Producer NFs register with a network function repository function (NRF). The NRF maintains an NF profile of available NF instances and their supported services. Consumer NFs can subscribe to receive information about producer NF instances that have registered with the NRF.

In addition to consumer NFs, another type of network node that can subscribe to receive information about NF service instances is a service communications proxy (SCP). The SCP subscribes with the NRF and obtains reachability and service profile information regarding producer NF service instances. Consumer NFs connect to the service communications proxy, and the service communications proxy load balances traffic among producer NF service instances that provide the required service or directly routes the traffic to the destined producer NF.

One problem with the existing 3GPP service architecture is that a consumer NF or an SCP may have insufficient information to load balance traffic among service endpoints exposed by a producer NF service instance. In one scenario, a producer NF may only register its FQDN at the NF service level without individually registering domain names, IP addresses, or IP endpoints of producer NF services. In another scenario, a producer NF may only register its FQDN at the NF instance level without individually registering IP addresses or IP endpoints of services or FQDNs at the NF service level.

In either of these scenarios, the consumer NF or SCP must obtain the IP addresses or IP endpoints associated with the service endpoints to contact the individual service endpoints. In general, IP addresses or IP endpoints corresponding to domain names can be determined using the domain name system (DNS). In the 5G network architecture described above, service consumers need to be notified of service endpoint IP addresses whenever an NF registers or updates its profile. Another scenario in which the consumer NF or SCP needs to be updated with the IP addresses or IP endpoints of the service is when the IP addresses or IP endpoints change without a corresponding NF profile or service update. Even though IP addresses or IP endpoints are discoverable through DNS, there is no automated process for notifying service consumers when an IP address or IP endpoint associated with a service changes.

Accordingly, there exists a need for methods, systems, and computer readable for actively discovering and tracking addresses associated with 5G and non-5G service endpoints.

SUMMARY

A method for discovering and tracking addresses associated with producer network function (NF) service endpoints includes receiving a first domain name system (DNS) resolution request from a requesting node. The method further includes querying a DNS server using a fully qualified domain name (FQDN) extracted from the first DNS resolution request. The method further includes receiving a first response from the DNS server, the first response including an address associated with a producer NF service endpoint associated with the FQDN. The method further includes storing the address associated with the producer NF service endpoint in a database. The method further includes communicating the address associated with the producer NF service to the requesting node. The method further includes monitoring the FQDN for changes in address associated with the FQDN. The method further includes notifying the requesting node of the changes in address associated with the FQDN.

According to an aspect of the subject matter described herein, receiving the first DNS resolution request includes receiving the first DNS resolution request from a service communications proxy (SCP).

According to another aspect of the subject matter described herein, receiving the first DNS resolution request includes receiving the first DNS resolution request from a consumer NF or a non-5G service consumer.

According to yet another aspect of the subject matter described herein, receiving the first DNS resolution request includes receiving the first DNS resolution request at a representational state transfer (REST) server interface provided by a DNS discoverer micro-service.

According to yet another aspect of the subject matter described herein, querying the DNS server includes querying the DNS server from a DNS discoverer micro-service separate from the consumer NF or SCP and the DNS server. In this context, "separate from" means that the DNS discoverer micro-service is implemented on a computing platform separate from a consumer NF or SCP that needs to resolve a domain name and also separate from a computing platform that hosts the DNS server. In an alternate implementation, the DNS discoverer micro-service may be implemented on the same computing platform as a consumer NF or an SCP.

According to yet another aspect of the subject matter described herein, storing the address associated with the producer NF service comprises storing the address in a database local to the DNS discoverer micro-service along with the time to live of each address received from the DNS Server.

According to yet another aspect of the subject matter described herein, for every address received from the DNS server along with a time to live value when stored in a record in the database, a timer is started for the time period received in time to live field.

According to yet another aspect of the subject matter described herein, monitoring the FQDN comprises: detecting expiration of a record storing the address associated with the producer NF service in the database; in response to detecting expiration of the record, querying the DNS server using the FQDN; receiving a second response from the DNS server; comparing an address in the second response to the address stored in the record in the database; and determining that a change in address associated with the FQDN has occurred in response to the address in the second response being different from the address stored in the record in the database.

According to yet another aspect of the subject matter described herein, the address associated with the producer NF service instance comprises an Internet protocol (IP) address or an IP endpoint.

According to yet another aspect of the subject matter described herein, monitoring the FQDN for changes address includes continually monitoring the FQDN for changes in address until stopped in response to a message from the requesting node to cease monitoring the FQDN.

According to yet another aspect of the subject matter described herein, the message from the requesting node to cease monitoring the FQDN comprises a second DNS resolution request including a DELETE method type, and, in response, ceasing monitoring the FQDN.

According to yet another aspect of the subject matter described herein, the DNS discoverer micro-service includes a representational state transfer (REST) server interface to cease the monitoring of FQDN from the requesting node.

According to yet another aspect of the subject matter described herein, a system for discovering and tracking producer network function (NF) service endpoints, comprises a computing platform including at least one processor. The system further includes a domain name system (DNS) discover micro-service located on the computing platform and implemented by the at least one processor for receiving a first domain name system (DNS) resolution request, querying a DNS server using a fully qualified domain name (FQDN) extracted from the first DNS resolution request, receiving a first response from the DNS server, the first response including an address associated a producer NF service endpoint associated with the FQDN, storing the address associated with the producer NF service endpoint in a database, communicating the address associated with the producer NF service endpoint to the requesting node, monitoring the FQDN for changes in address associated with the FQDN, and notifying the requesting node of the changes in address associated with the FQDN.

According to yet another aspect of the subject matter described herein, the DNS discoverer micro-service is configured to receive the first DNS resolution request from a service communications proxy (SCP).

According to yet another aspect of the subject matter described herein, the DNS discoverer micro-service is configured to the first DNS resolution request from a consumer NF or a non-5G service consumer.

According to yet another aspect of the subject matter described herein, the DNS discoverer micro-service includes a representational state transfer (REST) server interface for receiving the first DNS resolution request from the requesting node.

According to yet another aspect of the subject matter described herein, the computing platform and the DNS discoverer micro-service are separate from the requesting node and the DNS server.

According to yet another aspect of the subject matter described herein, the database is local to the DNS discoverer micro-service.

According to yet another aspect of the subject matter described herein, the DNS discoverer micro-service includes a DNS records change discoverer for performing the monitoring of the FQDN by: detecting expiration of a record storing the address associated with the producer NF service endpoint in the database; in response to detecting expiration of the record, querying the DNS server using the FQDN; receiving a second response from the DNS server; and comparing an address in the second response to the address stored in the record in the database; determining that a change in address associated with the FQDN has occurred in response to the address in the second response being different from the address or stored in the record in the database.

According to yet another aspect of the subject matter described herein, the address associated with the producer NF service endpoint comprises an Internet protocol (IP) address or an IP endpoint.

According to yet another aspect of the subject matter described herein, the DNS record change discoverer is configured to continually monitor the FQDN for changes address associated with the FQDN until stopped in response to a message from the requesting node to cease monitoring the FQDN.

According to yet another aspect of the subject matter described herein, a non-transitory computer readable medium having stored thereon executable instructions that when executed by a processor of a computer control the computer to perform steps is provided. The steps include receiving a first domain name system (DNS) resolution request from a requesting node. The steps include querying a DNS server using a fully qualified domain name (FQDN) extracted from the first DNS resolution request. The steps further include receiving a first response from the DNS server, the response including an address associated with a producer NF service endpoint associated with the FQDN. The steps further include storing the address associated with the producer NF service endpoint in a database. The steps further include communicating the address associated with the producer NF service endpoint to the requesting node. The steps further include monitoring the FQDN for changes in address associated with the FQDN. The steps further include notifying the requesting node of the changes in address associated with the FQDN.

The subject matter described herein may be implemented in hardware, software, firmware, or any combination thereof. As such, the terms "function" "node" or "module" as used herein refer to hardware, which may also include software and/or firmware components, for implementing the feature being described. In one exemplary implementation, the subject matter described herein may be implemented using a computer readable medium having stored thereon computer executable instructions that when executed by the processor of a computer control the computer to perform steps. Exemplary computer readable media suitable for implementing the subject matter described herein include non-transitory computer-readable media, such as disk memory devices, chip memory devices, programmable logic devices, and application specific integrated circuits. In addition, a computer readable medium that implements the subject matter described herein may be located on a single device or computing platform or may be distributed across multiple devices or computing platforms.

BRIEF DESCRIPTION OF THE DRAWINGS

The subject matter described herein will now be explained with reference to the accompanying drawings of which:

FIG. **1** is a network diagram illustrating an exemplary 5G network architecture;

FIG. **2** is a network diagram illustrating load balancing by a service communications proxy among 5G producer NF service instances and service endpoints exposed by the 5G producer NF service instances;

FIG. **3** is a network diagram illustrating a DNS discoverer micro-service that enables a consumer NF or SCP to discover address information associated with producer NF service endpoints;

FIG. **4** is a call flow diagram illustrating exemplary messaging for obtaining address information for producer NF service endpoints using a DNS discoverer micro-service;

FIG. **5** is a call flow diagram illustrating a DNS change monitor and control flow using the DNS discoverer micro-service;

FIG. **6** is a call flow diagram illustrating a stop DNS call flow using a DNS discoverer micro-service;

FIG. **7** is a block diagram illustrating a network node implementing a DNS discoverer micro-service; and

FIG. **8** is a flow chart illustrating an exemplary process for discovering and monitoring address information associated with 5G and non-5G service endpoints using the DNS discoverer micro-service.

DETAILED DESCRIPTION

The subject matter described herein relates to methods, systems, and computer readable media for discovering and actively tracking address information associated with 5G and non-5G service endpoints. FIG. **1** is a block diagram illustrating an exemplary 5G system network architecture. The architecture in FIG. **1** includes NRF **100** and SCP **101**, which may be located in the same home public land mobile network (HPLMN). As described above, NRF **100** may maintain profiles of available producer NF service instances and their supported services and allow consumer NFs or SCPs to subscribe to and be notified of the registration of new/updated producer NF service instances. SCP **101** may also support service discovery and selection of producer NFs. In addition, SCP **101** may perform load balancing of connections between consumer and producer NFs.

NRF **100** is a repository for NF profiles. In order to communicate with a producer NF, a consumer NF or an SCP must obtain the NF profile from NRF **100**. The NF profile is a JSON data structure defined in 3GPP TS 29.510. Table 1 shown below illustrates attributes of the NF profile as defined in 3GPP TS 29.510.

TABLE 1

NF Profile Definition

Attribute name	Data type	P	Cardinality	Description
nfInstanceId	NfInstanceId	M	1	Unique identity of the NF Instance.
nfType	NFType	M	1	Type of Network Function
nfStatus	NFStatus	M	1	Status of the NF Instance (NOTE 5)
heartBeatTimer	integer	C	0..1	Time in seconds expected between 2 consecutive heart-beat messages from an NF Instance to the NRF. It may be included in the registration request. When present in the request it shall contain the heartbeat time proposed by the NF service consumer. It shall be included in responses vfrom NRF to registration requests (PUT) or in NF profile updates (PUT or PATCH). If the proposed heartbeat time is acceptable by the NRF based on the local configuration, it shall use the same value as in the registration request; otherwise the NRF shall override the value using a preconfigured value.
plmnList	array(PlmnId)	C	1..N	PLMN(s) of the Network Function (NOTE 7). This IE shall be present if this information is available for the NF. If not provided, PLMN ID(s) of the PLMN of the NRF are assumed for the NF.
sNssais	array(Snssai)	O	1..N	S-NSSAIs of the Network Function. If not provided, the NF can serve any S-NSSAI. When present this IE represents the list of S-NSSAIs supported in all the PLMNs listed in the plmnList IE.
perPlmnSnssaiList	array(PlmnSnssai)	O	1..N	This IE may be included when the list of S-NSSAIs supported by the NF for each PLMN it is supporting is different. When present, this IE shall include the S-NSSAIs supported by the Network Function for each PLMN supported by the Network Function. When present, this IE shall override sNssais IE. (NOTE 9)

TABLE 1-continued

NF Profile Definition				
Attribute name	Data type	P	Cardinality	Description
nsiList	array(string)	O	1..N	NSI identities of the Network Function. If not provided, the NF can serve any NSI.
Fqdn	Fqdn	C	0..1	FQDN of the Network Function (NOTE 1) (NOTE 2). For AMF, the FQDN registered with the NRF shall be that of the AMF Name (see 3GPP TS 23.003 [12] clause 28.3.2.5).
interPlmnFqdn	Fqdn	C	0..1	If the NF needs to be discoverable by other NFs in a different PLMN, then an FQDN that is used for inter-PLMN routing as specified in 3GPP TS 23.003 [12] shall be registered with the NRF (NOTE 8). A change of this attribute shall result in triggering a "NF_PROFILE_CHANGED" notification from NRF towards subscribing NFs located in a different PLMN, but the new value shall be notified as a change of the "fqdn" attribute.
ipv4Addresses	array(Ipv4Addr)	C	1..N	IPv4 address(es) of the Network Function (NOTE 1) (NOTE 2)
ipv6Addresses	array(Ipv6Addr)	C	1..N	IPv6 address(es) of the Network Function (NOTE 1) (NOTE 2)
allowedPlmns	array(PlmnId)	O	1..N	PLMNs allowed to access the NF instance. If not provided, any PLMN is allowed to access the NF. A change of this attribute shall not trigger a "NF_PROFILE_CHANGED" notification from NRF, and this attribute shall not be included in profile change notifications to subscribed NFs.
allowedNfTypes	array(NFType)	O	1..N	Type of the NFs allowed to access the NF instance. If not provided, any NF type is allowed to access the NF. A change of this attribute shall not trigger a "NF_PROFILE_CHANGED" notification from NRF, and this attribute shall not be included in profile change notifications to subscribed NFs.
allowedNfDomains	array(string)	O	1..N	Pattern (regular expression according to the ECMA-262 dialect [8]) representing the NF domain names allowed to access the NF instance. If not provided, any NF domain is allowed to access the NF. A change of this attribute shall not trigger a "NF_PROFILE_CHANGED" notification from NRF, and this attribute shall not be included in profile change notifications to subscribed NFs.
allowedNssais	array(Snssai)	O	1..N	S-NSSAI of the allowed slices to access the NF instance. If not provided, any slice is allowed to access the NF. A change of this attribute shall not trigger a "NF_PROFILE_CHANGED" notification from NRF, and this attribute shall not be included in profile change notifications to subscribed NFs.

TABLE 1-continued

NF Profile Definition				
Attribute name	Data type	P	Cardinality	Description
Priority	integer	O	0..1	Priority (relative to other NFs of the same type) in the range of 0-65535, to be used for NF selection; lower values indicate a higher priority. If priority is also present in the nfServiceList parameters, those will have precedence over this value. (NOTE 4). The NRF may overwrite the received priority value when exposing an NFProfile with the Nnrf_NFDiscovery service.
Capacity	integer	O	0..1	Static capacity information in the range of 0-65535, expressed as a weight relative to other NF instances of the same type; if capacity is also present in the nfServiceList parameters, those will have precedence over this value. (NOTE 4).
Load	integer	O	0..1	Dynamic load information, ranged from 0 to 100, indicates the current load percentage of the NF.
Locality	string	O	0..1	Operator defined information about the location of the NF instance (e.g. geographic location, data center) (NOTE 3)
udrInfo	UdrInfo	O	0..1	Specific data for the UDR (ranges of SUPI, group ID . . .)
udm Info	Udm Info	O	0..1	Specific data for the UDM (ranges of SUPI, group ID . . .)
ausfInfo	AusfInfo	O	0..1	Specific data for the AUSF (ranges of SUPI, group ID...)
amfInfo	AmfInfo	O	0..1	Specific data for the AMF (AMF Set ID, . . .)
smfInfo	SmfInfo	O	0..1	Specific data for the SMF (DNN's, . . .)
upfInfo	UpfInfo	O	0..1	Specific data for the UPF (S-NSSAI, DNN, SMF serving area, interface . . .)
pcfInfo	PcfInfo	O	0..1	Specific data for the PCF
bsfInfo	BsfInfo	O	0..1	Specific data for the BSF
chfInfo	ChfInfo	O	0..1	Specific data for the CHF
nrfInfo	NrfInfo	O	0..1	Specific data for the NRF
custom Info	object	O	0..1	Specific data for custom Network Functions
recoveryTime	DateTime	O	0..1	Timestamp when the NF was (re)started (NOTE 5) (NOTE 6)
nfServicePersistence	boolean	O	0..1	If present, and set to true, it indicates that the different service instances of a same NF Service in this NF instance, supporting a same API version, are capable to persist their resource state in shared storage and therefore these resources are available after a new NF service instance supporting the same API version is selected by a NF Service Consumer (see 3GPP TS 23.527 [27]). Otherwise, it indicates that the NF Service Instances of a same NF Service are not capable to share resource state inside the NF Instance.
nfServices	array(NFService)	O	1..N	List of NF Service Instances. It shall include the services produced by the NF that can be discovered by other NFs, if any.
nfProfileChanges SupportInd	boolean	O	0..1	NF Profile Changes Support Indicator. See Annex B. This IE may be present in the NFRegister or NFUpdate (NF Profile Complete Replacement) request and shall be absent in the response. true: the NF Service Consumer

TABLE 1-continued

NF Profile Definition

Attribute name	Data type	P	Cardinality	Description
				supports receiving NF Profile Changes in the response. false (default): the NF Service Consumer does not support receiving NF Profile Changes in the response. Write-Only: true
nfProfileChangesInd	boolean	O	0..1	NF Profile Changes Indicator. See Annex B. This IE shall be absent in the request to the NRF and may be included by the NRF in NFRegister or NFUpdate (NF Profile Complete Replacement) response. true: the NF Profile contains NF Profile changes. false (default): complete NF Profile. Read-Only: true
defaultNotification Subscriptions	array(DefaultNotificationSubscription)	O	1..N	Notification endpoints for different notification types. (NOTE 10)

NOTE 1

At least one of the addressing parameters (fqdn, ipv4address or ipv6adress) shall be included in the NF Profile. If the NF supports the NF services with "https" URI scheme (i.e use of TLS is mandatory), then the FQDN shall be provided in the NF Profile or the NF Service profile (see clause 6.1.6.2.3). See NOTE 1 of Table 6.1.6.2.3-1 for the use of these parameters. If multiple ipv4 addresses and/or ipv6 addresses are included in the NF Profile, the NF Service Consumer of the discovery service shall select one of these addresses randomly, unless operator defined local policy of IP address selection, in order to avoid overload for a specific ipv4 address and/or ipv6 address.

NOTE 2

If the type of Network Function is UPF, the addressing information is for the UPF N4 interface.

NOTE 3

A requester NF may use this information to select a NF instance (e.g. a NF instance preferably located in the same data center).

NOTE 4

The capacity and priority parameters, if present, are used for NF selection and load balancing. The priority and capacity attributes shall be used for NF selection in the same way that priority and weight are used for server selection as defined in IETF RFC 2782 [23].

NOTE 5

The NRF shall notify NFs subscribed to receiving notifications of changes of the NF profile, if the NF recoveryTime or the nfStatus is changed. See clause 6.2 of 3GPP TS 23.527 [27].

NOTE 6

A requester NF may consider that all the resources created in the NF before the NF recovery time have been lost. This may be used to detect a restart of a NF and to trigger appropriate actions, e.g. release local resources. See clause 6.2 of 3GPP TS 23.527 [27].

NOTE 7

A NF may register multiple PLMN IDs in its profile within a PLMN comprising multiple PLMN IDs. If so, all the attributes of the NF Profile shall apply to each PLMN ID registered in the plmnList. As an exception, attributes including a PLMN ID, e.g. IMSI-based SUPI ranges, TAIs and GUAMIs, are specific to one PLMN ID and the NF may register in its profile multiple occurrences of such attributes for different PLMN IDs (e.g. the UDM may register in its profile SUPI ranges for different PLMN IDs).

NOTE 8

Other NFs are in a different PLMN if they belong to none of the PLMN ID(s) configured for the PLMN of the NRF.

NOTE 9

This is for the use case where an NF (e.g. AMF) supports multiple PLMNs and the slices supported in each PLMN are different. See clause 9.2.6.2 of 3GPP TS 38.413 [29].

NOTE 10

If notification endpoints are present both in the profile of the NF instance (NFProfile) and in some of its NF Services (NFService) for a same notification type, the notification endpoint(s) of the NF Services shall be used for this notification type.

As indicated in Table 1, the NF profile definition includes at least one of an FQDN, an IP version 4 address or an IP version 6 address. However, there is no requirement that the NF profile include individual IP addresses or IP endpoints associated with a producer NF service endpoint located on the producer NF service instance.

In FIG. **1**, any of the nodes (other than SCP **101** and NRF **101**) can be either consumer NFs or producer NFs, depending on whether they are requesting or providing services. In the illustrated example, the nodes include a policy control function (PCF) **102** that performs policy related operations in a network, a user data management (UDM) function **104** that manages user data, and an application function (AF) **106** that provides application services. The nodes illustrated in FIG. **1** further include a session management function (SMF) **108** that manages sessions between access and mobility management function (AMF) **110** and PCF **102**. AMF **110** performs mobility management operations similar to those performed by a mobility management entity (MME) in 4G networks. An authentication server function (AUSF) **112** performs authentication services for user equipment (UEs), such as UE **114**, seeking access to the network.

A network slice selection function (NSSF) **116** provides network slicing services for devices seeking to access specific network capabilities and characteristics associated with a network slice. A network exposure function (NEF) **118** provides application programming interfaces (APIs) for application functions seeking to obtain information about Internet of things (loT) devices and other UEs attached to the network. NEF **118** performs similar functions to the service capability exposure function (SCEF) in 4G networks.

A radio access network (RAN) **120** connects UE **114** to the network via a wireless link. Radio access network **120** may be accessed using a g-Node B (gNB) (not shown in

FIG. **1**) or other wireless access point. A user plane function (UPF) **122** can support various proxy functionality for user plane services. One example of such proxy functionality is multipath transmission control protocol (MPTCP) proxy functionality. UPF **122** may also support performance measurement functionality, which may be used by UE **114** to obtain network performance measurements. Also illustrated in FIG. **1** is a data network (DN) **124** through which UEs access data network services, such as Internet services.

Address information associated with service endpoints resident on any of the NFs illustrated in FIG. **1** that provide services can be tracked using the DNS discoverer micro-service described herein. In addition, non-5G service endpoints that provide services under given FQDN may be discovered and tracked by the DNS discover micro-service described herein. Thus, the term "producer NF service endpoint" as used herein is intended to refer to a service endpoint present on any of the 5G or non-5G service provider nodes. Non-5G service provider nodes include 3G, 4G, or subsequent generation (post-5G) counterpart and non-3GPP service provider nodes.

As stated above, producer NFs register their NF profiles with the NRF. Consumer NFs can discover producer NFs that have registered to provide a specific service by obtaining the NF profiles from the NRF. Consumer NFs can communicate directly with NF service producer NFs. Alternatively, consumer NFs can communicate indirectly with producer NFs via the SCP. In the direct communications mode, the consumer NF performs discovery of the target producer NF either by local configuration or via the NRF. The consumer NF then communicates directly with the target service producer NF. In indirect communications mode, the consumer NF sends service request messages to the SCP, and the SCP may perform service discovery and selection of a producer NF on behalf of a consumer NF. In either the direct or indirect communications mode, the DNS discoverer micro-service described herein may receive DNS resolution request from the consumer NF or from the SCP, query a DNS server on behalf of the consumer NF or SCP, communicate the address information associated with producer NF service endpoints to the consumer NF or SCP, and continually monitor the FQDN received in the DNS resolution request for changes in address associated with the FQDN.

One problem that occurs in the architecture illustrated in FIG. **1** is that the service communication proxy or consumer NF may have insufficient information to load balance among service endpoints resident on producer NF service instances. FIG. **2** illustrates this problem. Referring to FIG. **2**, service communications proxy **101** resides between 5G consumer NFs **200** and **202** and 5G producer NFs **204** and **206**. 5G producer NF **204** includes producer NF service endpoints **204**A and **204**B. 5G producer NF service instance **206** includes producer NF service endpoints **206**A and **206**B.

In operation, consumer NFs **200** and **202** connect to service communications proxy **101**, and service communications proxy **101** load balances traffic among the producer NF service endpoints. Service communications proxy **101** determines producer NF service endpoints for load balancing from the above-described NF profile and NF service contents that producer NFs **204** and **206** have registered with NRF **100**. However, as indicated above, because registering the address information associated with the individual service endpoints is not required, the load balancing performed by SCP **101** may not evenly balance a load among service endpoints.

As indicated above, in one scenario, a producer NF service instance may only register a fully qualified domain name at the NF service level. In another scenario, no IP endpoints and no fully qualified domain name may be registered at the NF service level and only the fully qualified domain name may be registered at the NF instance level. In either of these scenarios, the service communications proxy lacks sufficient information for adequate load balancing.

The service communications proxy may determine the IP endpoints of service instances directly by the NF service or NF service instance through DNS-SRV records. In another example, the IP addresses may be exposed by the NF service or NF service instance through DNS A/AAAA records and ports are taken as SCP configuration.

The addresses of producer NF service endpoints need to be known to the SCP when any NF registers or updates a registration. The addresses of producer NF service endpoints also need to be known when the IP addresses or IP endpoints change without any NF profile or NF service updates. The SCP needs to track these changes for continued routing and load balancing purposes. The DNS discoverer micro-service described herein discovers addresses of producer NF service endpoints and monitors FQDNs for changes in address associated with the FQDN.

As indicated above, the DNS discoverer (DNS-D) micro-service solves at least some of the problems associated with discovery and tracking of service endpoints. The DNS discoverer micro-service queries DNS servers to obtain address information for producer NF service endpoints and provides that information to an SCP or consumer NF. FIG. **3** is a network diagram illustrating a network architecture that includes the DNS discoverer micro-service. Referring to FIG. **3**, DNS discoverer micro-service **300** may be implemented on a computing platform separate from or the same as SCP micro-services or consumer NF **302**. DNS discoverer micro-service **300** includes a DNS discoverer DNS client **304** that interfaces with external DNS servers **306**. DNS discoverer micro-service **300** also includes a database adapter **308** that maintains NF service endpoint information in a persistent database **310**. DNS discoverer micro-service **300** includes a DNS discoverer server interface **312** that exposes the DNS discoverer micro-service to SCP micro-services or consumer NF **302** or non-5G service consumers. In the illustrated example, server interface **312** is a representational state transfer (REST) interface that interfaces with a REST client **314** provided by SCP micro-service **302**. DNS discoverer micro-service **300** further includes a DNS discoverer REST client **316** that interfaces with a server interface **318** of SCP micro-services or consumer NF **302**.

DNS discoverer micro-service **300** can be used to resolve the challenge(s) identified above. In one example, DNS discoverer micro-service **300** may expose a REST/HTTP interface to listen for DNS resolution/Monitoring requests from an SCP or any other service consumer(s). Consumer(s) send DNS requests as HTTP POST messages with callback uniform resource indicators (URIs) where DNS responses are expected. Being an asynchronous service, DNS discoverer micro-service **300** sends back a 201 created message indicating a request is accepted. DNS discoverer micro-service **300** queries external DNS servers with the requested FQDN. After getting successful DNS resolution from these external DNS servers, DNS discoverer micro-service **300** sends a DNS response to the callback URI received in a DNS resolution request as an HTTP PUT request. DNS discoverer micro-service **300** caches/stores the DNS query responses from external DNS server(s) and the times to live

(TTLs) (received in the responses from the DNS servers) to enable DNS change monitoring (discussed below).

DNS discoverer micro-service **300** continually monitors (until stopped) all the requested FQDNs for the TTLs received in DNS query responses. DNS responses from external DNS servers are matched at every iteration with stored responses. Differences are indicated to the consumers in the callback URI as an HTTP PUT request. Consumer(s) may opt to stop monitoring by sending an HTTP DELETE request message to DNS discover micro-service **300**.

FIG. **4** is a call flow diagram illustrating DNS request servicing performed by DNS discoverer micro-service **300**. The DNS discoverer micro-service **300** includes the components illustrated in and described above with regard to FIG. **3**. In addition to the components illustrated in FIG. **3**, DNS discoverer micro-service **300** includes a DNS records change discoverer **400** that monitors requested fully qualified domain names for the time to live values received in DNS query responses, re-queries DNS servers **306** when TTLs have expired, and communicates changes in resolved IP addresses or IP endpoints to consumer NFs, SCPs, or non-5G service consumers.

Referring to the call flow in FIG. **4**, in line 1, a DNS consumer, such as SCP micro-services or consumer NF **302**, sends a DNS resolution request to server interface of DNS discoverer micro-service **300**. The DNS resolution request includes the FQDN to be resolved, the DNS query type, where the query type indicates an IP address or an IP endpoint, a cookie identifier, and a callback URI for DNS responses and updates sent on DNS discoverer REST client **316** to the querying DNS consumer.

In line 2 of the call flow diagram, DNS discoverer server interface **312** sends a response indicating that the request has been received and accepted.

In line 3 of the call flow diagram, DNS client component **304** of DNS discoverer micro-service **300** sends a query to external DNS servers **306** to resolve the fully qualified domain name in the DNS resolution request.

In line 4 of the call flow diagram, DNS servers **306** respond to DNS client **304** with a response to the DNS query. The response may include one or more IP addresses or IP endpoints that reside on a producer NF service instance corresponding to the FQDN in the DNS query.

In line 5 of the call flow diagram, DNS client component **304** communicates the IP address or IP endpoint information to DNS discoverer database adapter **308** and DNS discoverer database adapter **308** forwards the response to persistent database **310**. The response includes the fully qualified domain name from the DNS resolution request, the resolved IP address (or IP addresses and ports depending on the type of response), and expiration time, which is the lowest TTL value of all of the TTL values of DNS resource records received in the query response.

In line 6, DNS discoverer database adapter **308** sends a message to DNS discoverer REST client **316** indicating that the database record has been created, and DNS discoverer client **316** sends the DNS response to SCP micro-services or consumer NF **302**. The DNS response is sent on the callback URI received in the request. In line 7, SCP micro-services or consumer NF **302** sends a 200 OK response to DNS discoverer REST client **316**.

DNS records change discoverer **400** detects changes in resolved IP addresses or IP endpoints corresponding to a monitored FQDN. DNS records change discoverer **400** may periodically fetch all DNS records from storage and identify any records where the TTLs received in the DNS query responses have lapsed. For each record where the TTL has lapsed, DNS records change discoverer **400** may re-query the external DNS servers to determine any changes. If any changes have occurred, no further action is required. If a change has occurred, DNS records change discoverer **400** may notify consumer NFs or SCPs that are subscribed to the given service through a REST/HTTP PUT request on the call back URI received in the original DNS request. FIG. **5** is a call flow diagram illustrating a DNS change monitoring call flow. Referring to FIG. **5**, in line 1, DNS records change discoverer **400** calculates the current timestamp. In line 2, DNS records change discoverer **400** queries persistent database **310** for all records that have a TTL or expiry time that has lapsed. In line 3 of the call flow diagram, persistent database **310** returns DNS records with lapsed call flows to DNS records change discoverer **400**.

In line 4 of the call flow diagram, DNS records change discoverer **400** notifies DNS discoverer client **304** of each FQDN for which the TTL has lapsed. In line 5, DNS discoverer client **304** queries external DNS servers **306** for each FQDN for which the TTL has lapsed. In line 6 of the call flow diagram, DNS discoverer DNS client **304** receives a DNS query response for each FQDN queried in line 5. In line 7, DNS discoverer DNS client **304** notifies DNS records change discoverer of the IP addresses or IP endpoints received in the responses in line 6. DNS records change discoverer **400** determines whether the IP addresses or IP endpoints received match the stored data for each FQDN. If the IP addresses or IP endpoints match, no further action is required on the part of DNS record change discoverer **400**. However, if the IP addresses or IP endpoints do not match, in line 8, DNS records change discoverer **400** communicates the changed IP addresses or IP endpoints to DNS discoverer REST client **316**. DNS discoverer REST client **316** informs SCP micro-services or consumer NF **302** of the change in IP addresses or IP endpoints using an HTTP put request on the call back URI received in the original request. In line 9 of the call flow diagram, DNS SCP micro-services or consumer NF **302** acknowledge receipt of the DNS responses in line 8.

Another operation performed by DNS discoverer micro-service **300** is to stop DNS monitoring, for example, when a consumer NF or SCP notifies DNS discoverer micro-service **300** that the consumer NF or SCP desires to stop monitoring a given FQDN. FIG. **6** illustrates such a call flow. Referring to the call flow in FIG. **6**, in line 1, SCP micro-services or consumer NF **302** sends a DNS resolution request with the FQDN to be resolved but specifying the delete method to stop DNS monitoring for the FQDN. In line 2 of the call flow diagram, DNS discoverer server interface **312** responds to the client indicating that the request has been accepted. In line 3 of the call flow diagram, DNS discoverer server interface **312** notifies DNS discoverer database adapter **308** that the consumer desires to cease monitoring the FQDN. DNS discoverer database adapter **308** sends a message to persistent database **310** to remove or update the record from persistent database **310** corresponding to the FQDN and notification URL specified in the original DNS resolution request. The message in line 3 will stop the DNS records change discoverer **400** from re-querying DNS servers **306** for the FQDN for this particular consumer.

FIG. **7** is a block diagram illustrating an exemplary architecture for a computing platform including DNS discoverer micro-service **300**. Referring to FIG. **7**, computing platform **700** includes at least one processor **702** and a memory **704**. DNS discoverer micro-service **300** may be implemented by executable instructions embodied in memory **704**. In the illustrated example, DNS discoverer micro-service **300** includes DNS discoverer server interface **312**, DNS discoverer DNS client **304**, DNS discoverer REST client **316**, DNS discoverer database adapter **308**, and DNS records change discoverer **400**. Persistent database **310** may also reside in computing platform **700** for storing the IP addresses or IP endpoints for resolved FQDNs.

FIG. **8** is a flow chart illustrating an exemplary process for actively discovering and tracking address information associated with 5G and non-5G service endpoints. Referring to FIG. **8**, in step **800**, a DNS resolution request is received from a requesting node. For example, DNS discoverer micro-service **300** may receive a DNS resolution request with an FQDN from a DNS discoverer consumer, such as an SCP a consumer NF, or a non-5G service consumer.

In step **802**, a DNS server is queried using the FQDN in the DNS resolution request. For example, DNS discoverer micro-service **300** may query external DNS servers **306** using an FQDN in a DNS request received from a DNS discoverer consumer.

In step **804**, a DNS response is received from the DNS server and, in step **806**, the addresses of producer NF service endpoints are stored in the DNS discoverer database (i.e., in persistent database **310**). For example, DNS discoverer micro-service **300** may receive DNS responses from DNS servers **306** and store the IP addresses or IP endpoints associated with producer NF service endpoints in database **310**. In one example, the DNS resolution request from DNS discoverer micro-service **300** may be a DNS-A resolution request, and DNS servers **306** may return an IPv4 address or addresses corresponding to a service endpoint or endpoints associated with the FQDN. In another example, the DNS resolution request may be a DNS-AAAA request, and DNS servers **306** may return an IPv6 address or addresses corresponding to a service endpoint or endpoints associated with the FQDN. In yet another example, the DNS resolution request may be a DNS-SRV request, and DNS servers may return an IP address(es) and port number(s) corresponding to a service endpoint or endpoints associated with the FQDN.

In step **808**, a DNS response is sent to the requesting node. For example, DNS discoverer micro-service **300** may send a response to the requesting node including addresses associated with producer NF service endpoints received in the DNS response from DNS servers **306**.

In step **810**, FQDNs in the DNS discoverer database are monitored for changes in address. For example, DNS records change discoverer **400** may, for each FQDN whose TTL has expired in database **310**, query external DNS servers **306** to determine any IP address or IP endpoint changes.

In step **812**, the requesting node is notified of any changes in IP address or IP endpoint associated with the FQDN. For example, DNS records change discoverer **400** may notify SCP micro-services or consumer NF **302** of any detected changes in IP address(es) or IP endpoints associated with an FQDN for which SCP micro-services or consumer NF **302** has queried DNS discoverer micro-service **300**

Thus, the subject matter described herein includes a DNS discoverer micro-service that discovers IP addresses or IP endpoints associated with producer NF service endpoints and monitors FQDNs for changes in such addresses. One advantage of such a service is the fact that consumer NFs and SCPs are not required to discover or actively monitor producer NFs for changes in IP addresses or IP endpoints associated with a service. The consumer NF or SCP is only required to learn the FQDN of a service and communicate the FQDN to the DNS discoverer micro-service. In addition, because the DNS discoverer micro-service actively monitors FQDNs for changes in IP address or IP endpoint, load balancing by nodes, such as SCPs and consumer NFs, will be more evenly distributed among producer NF service endpoints.

It will be understood that various details of the presently disclosed subject matter may be changed without departing from the scope of the presently disclosed subject matter. Furthermore, the foregoing description is for the purpose of illustration only, and not for the purpose of limitation.

What is claimed is:

1. A method for discovering and tracking addresses associated with producer network function (NF) service endpoints, the method comprising:

receiving a first domain name system (DNS) resolution request from a requesting node;

querying a DNS server using a fully qualified domain name (FQDN) extracted from the first DNS resolution request;

receiving a first response from the DNS server, the first response including an address associated with a producer NF service endpoint associated with the FQDN;

storing the address associated with the producer NF service endpoint in a database;

communicating the address associated with the producer NF service endpoint to the requesting node;

monitoring the FQDN for changes in address associated with the FQDN, wherein monitoring the FQDN comprises:

detecting expiration of a record storing the address or associated with the producer NF service endpoint in the database;

in response to detecting expiration of the record, querying the DNS server using the FQDN;

receiving a second response from the DNS server;

comparing an address in the second response to the address associated with the FQDN stored in the record in the database; and

determining that a change address associated with the FQDN has occurred in response to the address in the second response being different from the address associated with the FQDN stored in the record in the database; and

notifying the requesting node of the changes in address associated with the FQDN.

2. The method of claim **1** wherein receiving the first DNS resolution request from a requesting node includes receiving the first DNS resolution request from a service communications proxy (SCP).

3. The method of claim **1** wherein receiving the first DNS resolution request from a requesting node includes receiving the first DNS resolution request from a consumer NF or a non-5G service consumer.

4. The method of claim **1** wherein receiving the first DNS resolution request include receiving the first DNS resolution request at a representational state transfer (REST) server interface provided by a DNS discoverer micro-service.

5. The method of claim **1** wherein querying the DNS server includes querying the DNS server from a DNS discoverer micro-service separate from the requesting node and the DNS server.

6. The method of claim **4** wherein storing the address associated with the producer NF service comprises storing the address in a database local to the DNS discoverer micro-service.

7. The method of claim **1** wherein the address associated with the producer NF service endpoint comprises an Internet protocol (IP) address or an IP endpoint.

8. The method of claim 1 wherein monitoring the FQDN for changes in address includes continually monitoring the FQDN for changes in address until stopped in response to a message from the requesting node to cease monitoring the FQDN.

9. The method of claim 8 wherein the message from the requesting node to cease monitoring the FQDN comprises a second DNS resolution request including a DELETE method type, and, in response, ceasing monitoring the FQDN.

10. A system for discovering and tracking addresses associated with producer network function (NF) service endpoints, the system comprising:

a computing platform including at least one processor and a non-transitory computer readable medium for storing instructions executable by the at least one processor; and

a domain name system (DNS) discover micro-service located on the computing platform and comprising computer-executable instructions stored in the non-transitory computer readable medium and executable by the at least one processor for receiving a first domain name system (DNS) resolution request from a requesting node, querying a DNS server using a fully qualified domain name (FQDN) extracted from the first DNS resolution request, receiving a first response from the DNS server, the first response including an address associated with a producer NF service endpoint associated with the FQDN, storing the address associated with the producer NF service endpoint in a database, communicating the address associated with the producer NF service endpoint to the requesting node, monitoring the FQDN for changes in address associated with the FQDN, and notifying the requesting node of the changes in address associated with the FQDN, wherein the DNS discoverer micro-service includes a DNS records change discoverer for performing the monitoring of the FQDN by:

detecting expiration of a record storing the address associated with the producer NF service endpoint in the database;

in response to detecting expiration of the record, querying the DNS server using the FQDN;

receiving a second response from the DNS server;

comparing an address in the second response to the address associated with the producer NF service endpoint stored in the record in the database; and

determining that a change in address associated with the FQDN has occurred in response to the address in the second response being different from the address associated with the producer NF service endpoint stored in the record in the database.

11. The system of claim 10 wherein the DNS discoverer micro-service is configured to receive the first DNS resolution request from a service communications proxy (SCP).

12. The system of claim 10 wherein the DNS discoverer micro-service is configured to the first DNS resolution request from a consumer NF or a non-5G service consumer.

13. The system of claim 10 wherein the DNS discoverer micro-service includes a representational state transfer (REST) server interface for receiving the first DNS resolution request from the requesting node.

14. The system of claim 10 wherein the computing platform and the DNS discoverer micro-service are separate from the requesting node and the DNS server.

15. The system of claim 14 wherein the database is local to the DNS discoverer micro-service.

16. The system of claim 10 wherein the address associated with the producer NF service endpoint comprises an Internet protocol (IP) address or an IP endpoint.

17. The system of claim 10 wherein the DNS record change discoverer is configured to continually monitor the FQDN for changes in address until stopped in response to a message from the requesting node to cease monitoring the FQDN.

18. A non-transitory computer readable medium having stored thereon executable instructions that when executed by a processor of a computer control the computer to perform steps comprising:

receiving a first domain name system (DNS) resolution request from a requesting node;

querying a DNS server using a fully qualified domain name (FQDN) extracted from the first DNS resolution request;

receiving a first response from the DNS server, the response including an address associated with a producer network function (NF) service endpoint associated with the FQDN;

storing the address associated with the producer NF service endpoint in a database;

communicating the address associated with the producer NF service endpoint to the requesting node;

monitoring the FQDN for changes in address associated with the FQDN, wherein monitoring the FQDN comprises:

detecting expiration of a record storing the address or associated with the producer NF service endpoint in the database;

in response to detecting expiration of the record, querying the DNS server using the FQDN;

receiving a second response from the DNS server;

comparing an address in the second response to the address associated with the FQDN stored in the record in the database; and

determining that a change address associated with the FQDN has occurred in response to the address in the second response being different from the address associated with the FQDN stored in the record in the database; and

notifying the requesting node of the changes in address associated with the FQDN.

* * * * *